Repco AUTO TECH

AUTO-TECH MASTERCLASS

Training for Master Technicians

Introduction to the Holden RG Colorado

Diesel Exhaust After-Treatment, DON'T GET BURNED!

Suction Control Valve Advanced Diagnostics

Fuel Adaptation Tables What do they *really* mean?

Common Rail Diesel Exhaust Smoke Diagnosis

Diagnostic Tips

2016.2
DIESEL DIAGNOSTICS

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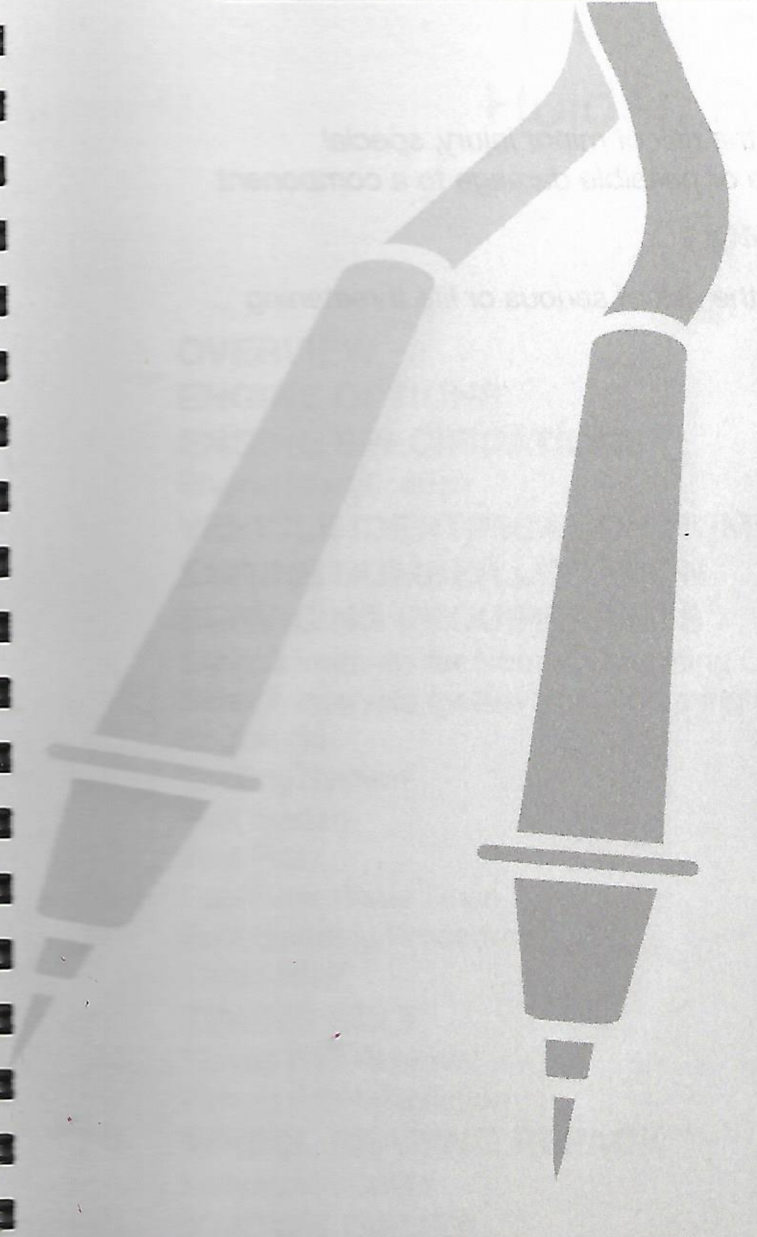

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Section i

Introduction to the Holden RG Colorado

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OVERVIEW

The Holden RG Colorado was released in 2012 as a full upgrade (body and driveline update) to the outgoing RC Colorado. As with the previous model the RG Colorado is built on the same platform as the Isuzu D-Max (and MU-X). However, there is now a much greater difference between the two 'sister' models.

The RG Colorado gained a new 'Duramax' engine, designed and engineered by VM Motori of Italy and built in the GMDaewoo facility in Rayong, Thailand. It also received a new 6 speed gearbox (auto and manual options). The D-Max carries on with the same 4JJ1 diesel engine and 5 speed transmissions.

The chassis and frame are still shared, although there are greater variations in the panel lines than the previous model. Inside the cabin, the dash panel and electronics are specific to the name plate, but the majority of the trim components are interchangeable.

ENGINE OPTIONS

The 'Duramax' engines in the RG Colorado are currently offered in five variations:

Model Year	Displacement	Holden Name	Holden Code	Output	VM Motori Code
2012-13 up to 09/13	2.5L Manual Only	Duramax	LVN	110kW @ 3800 RPM 350Nm @ 2000 RPM	R425
2012-13 up to 09/13	2.8L Manual	Duramax	LWH	132kW @ 3800 RPM 440Nm @ 2000 RPM	R428
2012-13 up to 09/13	2.8L Automatic	Duramax	LWH	132kW @ 3800 RPM 470Nm @ 2000 RPM	R428
2014 on from 10/13	2.8L Manual	Duramax 2	LWN	147kW @ 3800 RPM 440Nm @ 2000 RPM	A428
2014 on from 10/13	2.8L Automatic	Duramax 2	LWN	147kW @ 3800 RPM 500Nm @ 2000 RPM	A428

Note: *The 2.5L engine was only available in the base model (DX), single cab, RWD and five speed manual transmission option. It was discontinued prior to the 2014MY.*

In the United States these engines are known as "Baby Duramax" and are in no way related to the 6.6L V8 & 7.8L I6 truck engines offered in US trucks by General Motors.

VM Motori are part of the Fiat Group. During the development of the RG Colorado, GM owned 50% of VM Motori which invariably led to it being utilised. The VM Motori 4 cylinder CRD engines have been used in a variety of Chrysler/Jeep/Dodge vehicles in Australia and New Zealand.

R428 - 2.8L CRD
- Chrysler Grand Voyager (4th Gen.)
- Jeep Cherokee (KJ)

RA428 (variant of R428 specific to Chrysler/Jeep/Dodge)
- Chrysler Grand Voyager (5th Gen. 2008-2011)
- Dodge Nitro
- Jeep Cherokee (KK, 2007-2010)
- Jeep Wrangler (JK, 2007-2010)

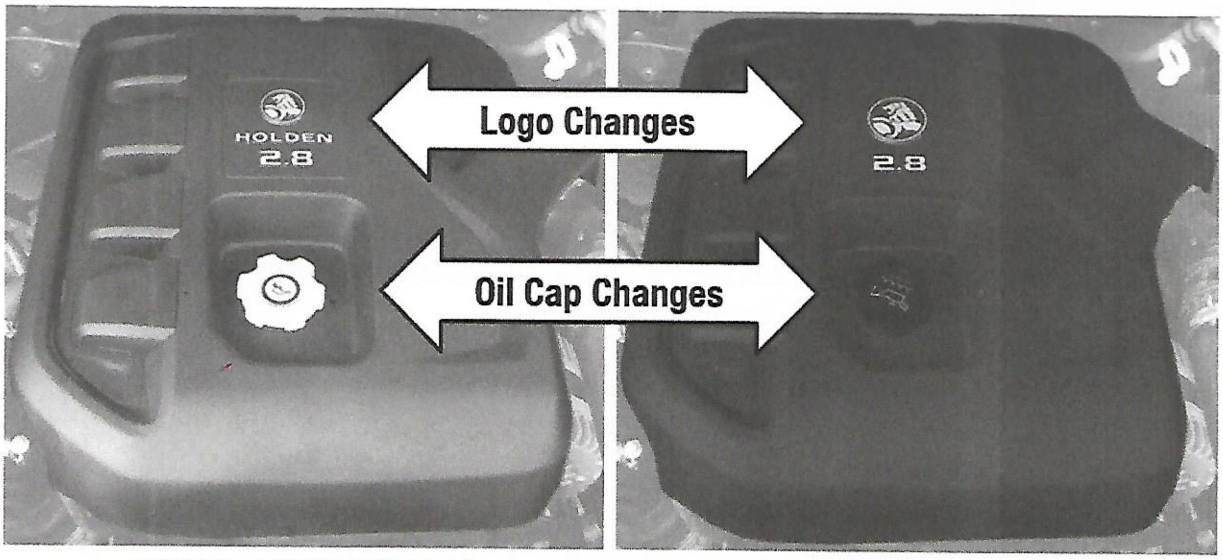
A428
- Chrysler Grand Voyager (5th Gen. 2011-2014)
- Jeep Cherokee (KK, 2010-2012)
- Jeep Wrangler (JK, 2010-2012)

Caution: *There are lots of similarities between the VM Motori engines used in Chrysler Group and GM vehicles. However, extreme caution must be used before swapping parts between marques as the engines are built in different facilities!*

ENGINE SPECIFICATIONS

	LVN 2.5L	LWH 2.8L	LWN 2.8L
Arrangement	4 Cylinder Inline		
Bore and Stroke	92mm x 94mm	94mm x 100mm	
Compression Ratio	16.5:1		
Valve Mechanism	DOHC 16 Valve		
Camshaft Drive	Belt		
Fuel Type	Ultra Low Sulphur Diesel		
Fuel System	Common Rail Diesel		
Fuel Pressure	up to 160MPa		up to 180MPa
Fuel Injectors	Solenoid		Piezo
Intake	Variable Geometry Turbocharger with Intercooler		
Firing Order	1 - 3 - 4 - 2		
Emissions Standard	EURO IV		

Engine Identification



2012-13MY

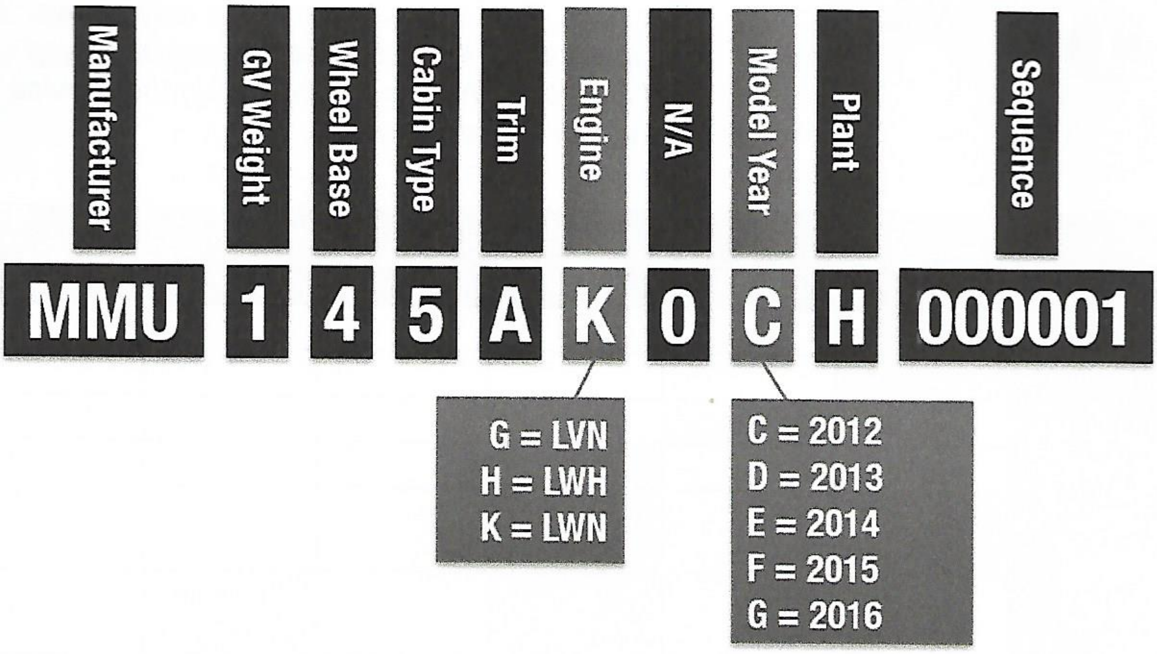
LWH - Duramax

2014-15MY

LWN Duramax 2

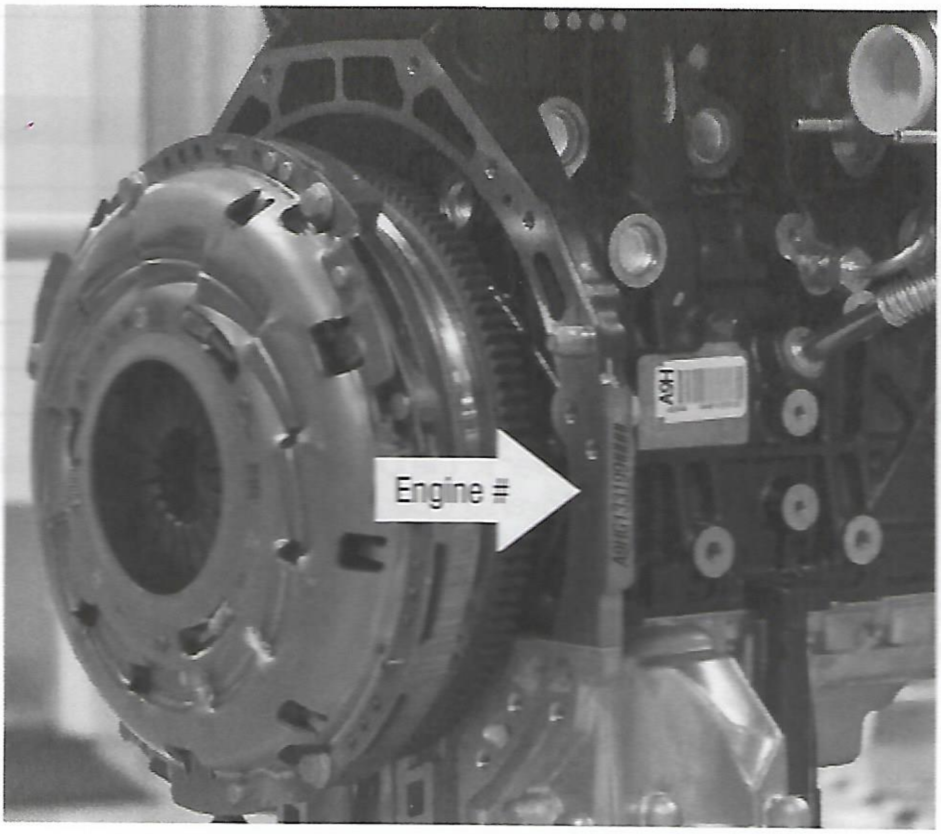
VEHICLE IDENTIFICATION NUMBER (VIN)

The following graphic shows the engine and model year identifiers within the VIN.


Manufacturer
GV Weight
Wheel Base
Cabin Type
Trim
Engine
N/A
Model Year
Plant
Sequence
MMU
1
4
5
A
K
0
C
H
000001
G = LVN
H = LWH
K = LWN
C = 2012
D = 2013
E = 2014
F = 2015
G = 2016

ENGINE NUMBER LOCATION

The engine number is located on the right rear side of the crankcase, directly behind the turbocharger. Engine number starts with A9H.



SERVICING REQUIREMENTS

Service Intervals for Normal Operating Conditions:

Note: *This is NOT a Service Schedule, it only shows the intervals of items that require replacement! Full Service Schedule is provided in the Service Manual or in SmartQuote.*

	Service Interval ,000kms/months					
	15/9	30/18	45/27	90/54	135/81	150/90
Engine Oil	X					
Oil Filter	X					
Fuel Filters		X				
Air Filter			X			
Front Wheel Bearings	Inspect		Re-pack			
Manual Trans			First		Then every 90/54	
Differentials				X		
Timing Belt						X
	Plus the following off sequence items					
Brake Fluid	Replace every 27 Months					
Clutch Fluid	Replace every 27 Months					
Coolant	Replace every 63 Months					

Service Intervals for Adverse Operating Conditions:

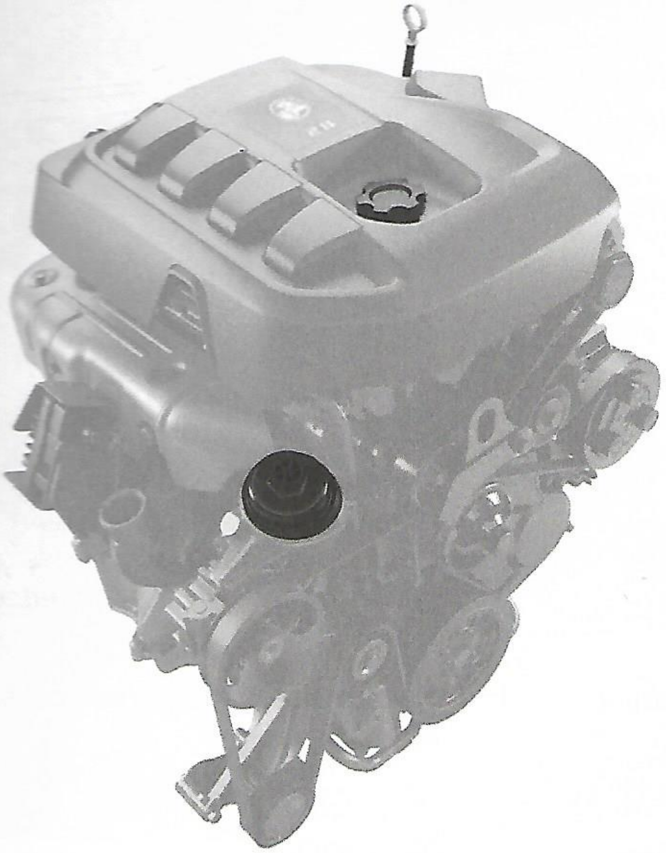
	Kilometres	Months
Inspection	7,500	N/A
Air Filter	15,000	9
Fuel Filter	15,000	9
Brake Fluid	N/A	12
Transfer Oil	75,000	N/A
A/T Fluid	75,000	N/A

Note: *Refer to the Owners Manual for a definition of Adverse Operating Conditions!*

SERVICING REQUIREMENTS continued...

Engine Oil

Oil Specification - DEXOS2
Oil Viscosity - 5W/30
Oil Quantity (LVN 4x2) - 7.6L
(LWH 4x2) - 6.7L
(LWH 4x4) - 6.4L
(LWN) - 5.6L
Sump Plug Tension - 25Nm
Oil Filter Type - Cartridge
Oil Filter Cap Tension - 25Nm



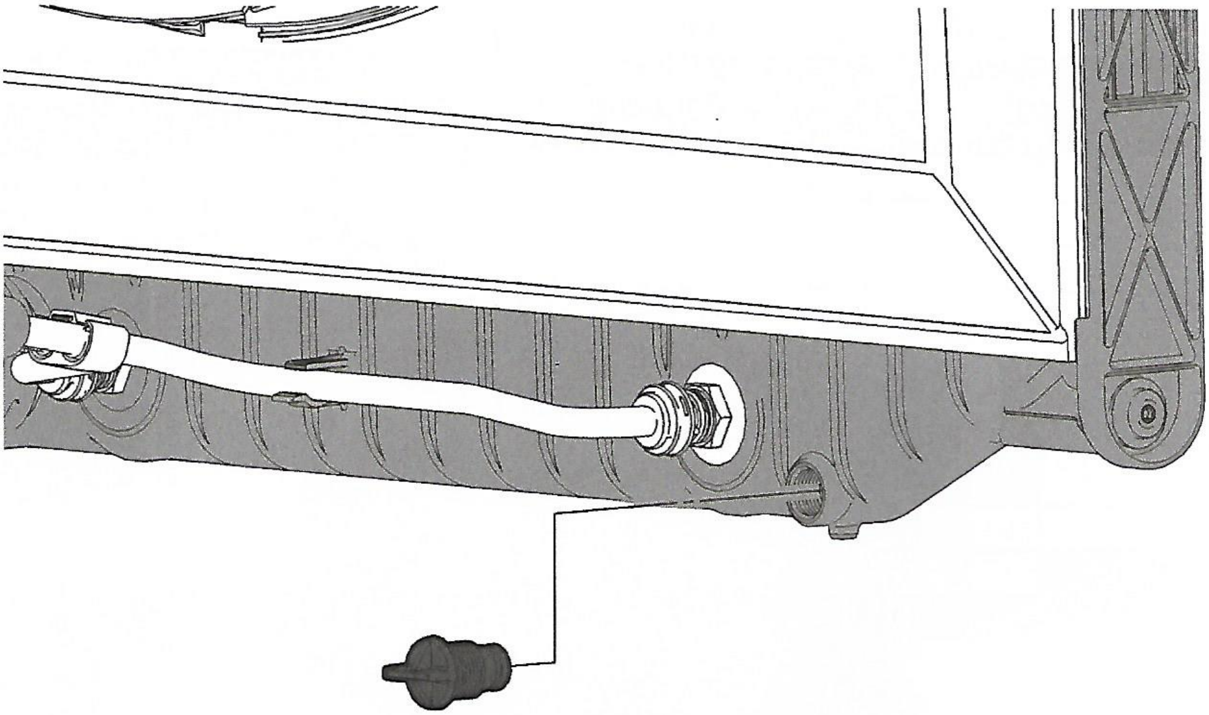
ⓘ *Note:* *Do NOT use open end spanner on the oil filter housings 27mm hexagon as it can damage the housing. Use only 12 or preferably 6 point sockets!*

⚠ *Caution:* *Holden states that it takes at least one hour of settling before an accurate oil level reading can be obtained!*

SERVICING REQUIREMENTS continued...

Cooling System

The RG Colorado utilises a pressurised reservoir tank, the system is self bleeding. There are no special requirements for the coolant change.
The system does not utilise an engine block drain, therefore a coolant change only requires the removal of the radiator drain plug.



Note: *Holden states that flushing is only required if the cooling system is contaminated!*

Caution: *Holden states that “chemical flushing agents” are not to be used!*

Coolant Specification - DEX-COOL
Coolant Dilution - 50:50 with potable (drinking) water
Cooling System Capacity - 9.0L

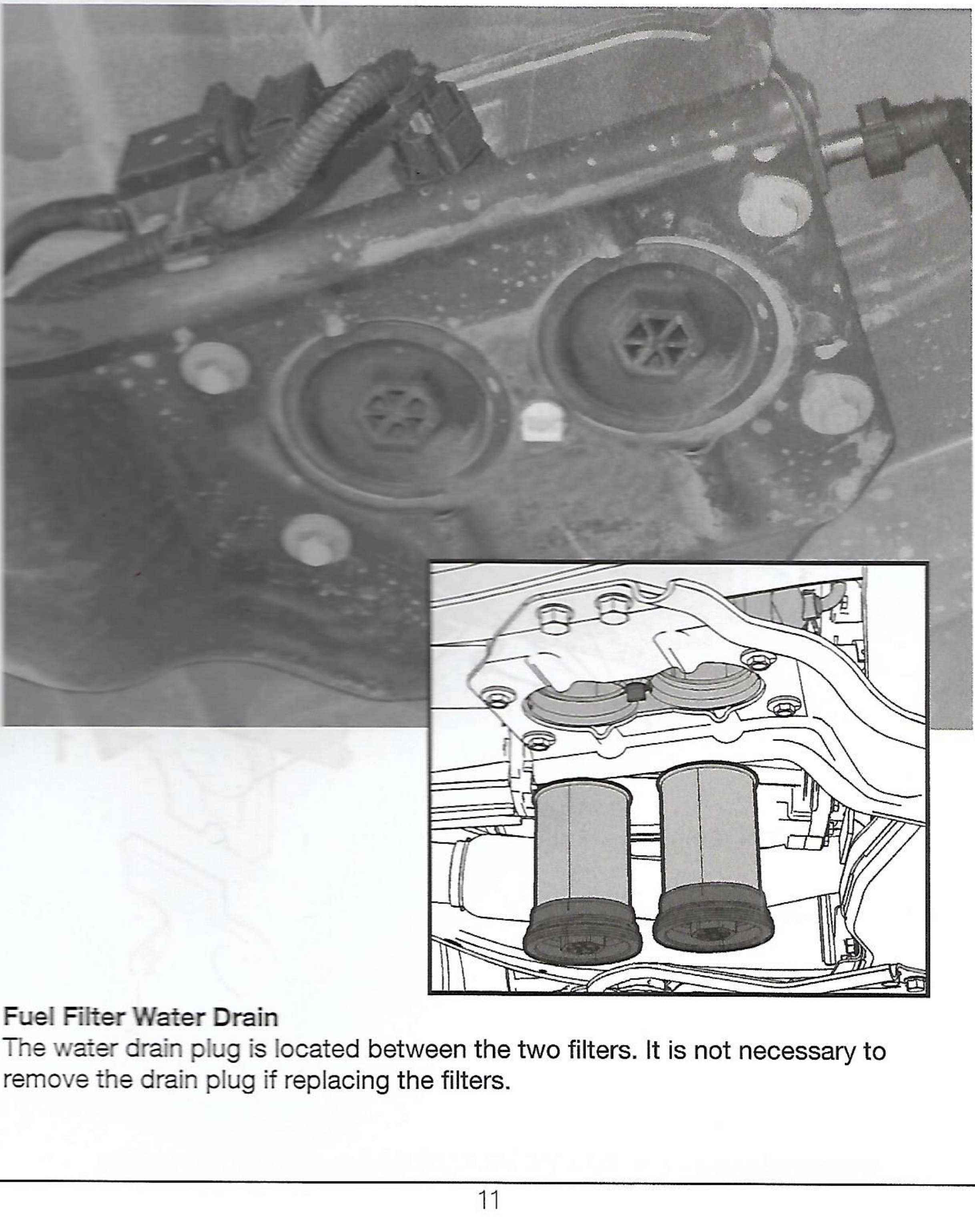
SERVICING REQUIREMENTS continued...

Fuel System

There are two fuel system variations used in the RG Colorado. The LVN & LWH (Duramax) engines use a 160MPa Denso Common Rail Injection System, the later LWN (Duramax2) engines use a 180MPa Denso Common Rail Injection System. Components are not interchangeable between the two variants.

Fuel Filter

The dual fuel filters are located on the LH Chassis Rail alongside the transmission. Both filters are of the same micron level which is not stated by the manufacturer.



Fuel Filter Water Drain

The water drain plug is located between the two filters. It is not necessary to remove the drain plug if replacing the filters.

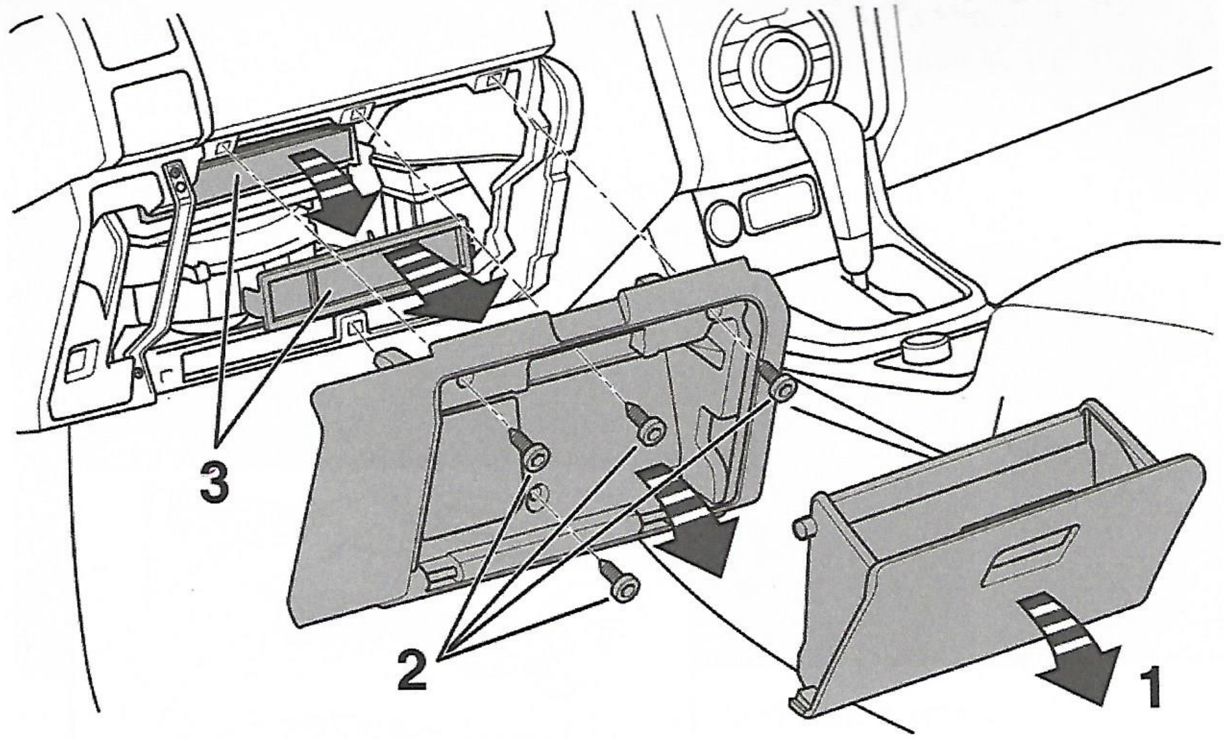
SERVICING REQUIREMENTS continued...

Fuel Bleeding Procedure

Holden states to turn the ignition ON for 30 seconds and then start the engine. If it stalls repeat.

Note: *When carrying out the bleeding process you will hear the air being purged through the return lines to the fuel tank. Auto-Tech recommends cycling the Ignition ON and OFF in 30 second intervals until air gurgling is no longer heard (usually 3-4 cycles). This method does not put significant strain on the electrical system and protects the high pressure system from being starved of lubricant!*

Cabin Filter



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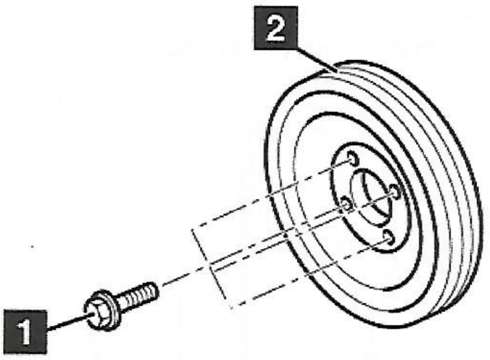
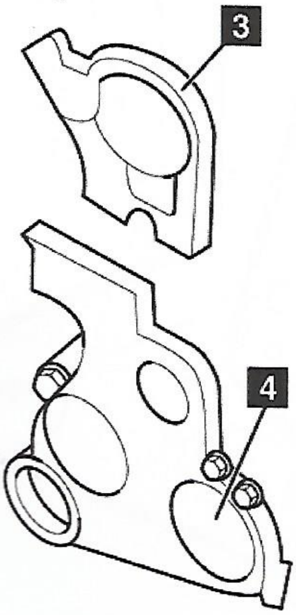
TIMING BELT

Timing Belt Removal

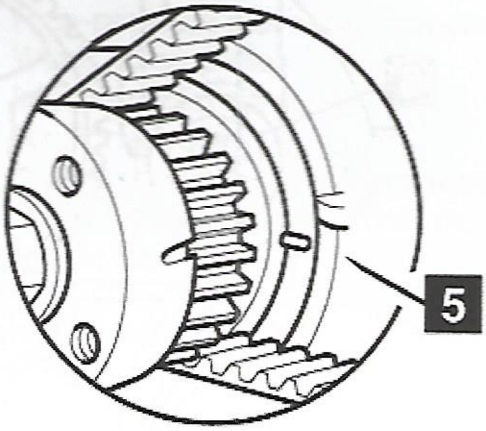
1. Raise and support front of vehicle
2. Drain coolant (if necessary)
3. Remove:
    - LH front wheel
    - LH front wheel arch liner
    - Engine top cover
    - Battery and battery tray
    - Front bumper assembly and trim (if necessary)
    - Intercooler to inlet manifold hose
    - Upper and lower fan cowling
    - Cooling fan and shroud
    - Viscous coupling
    - Front engine lifting eye
    - Auxiliary drive belt
    - Auxiliary drive belt guide pulleys
    - Cooling fan bracket
    - Crankshaft pulley bolts **1**
    - Crankshaft pulley **2**



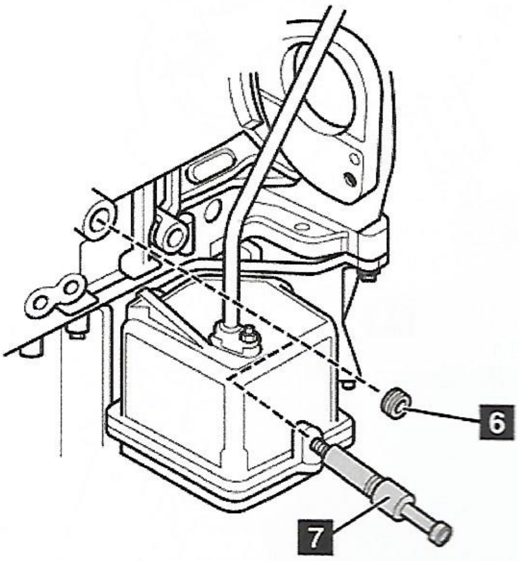
- Timing belt covers **3** & **4**



4. Turn crankshaft clockwise until crankshaft sprocket timing marks at 3 o'clock position **5**



5. Remove blanking plug from cylinder block **6**
6. Fit crankshaft locking tool **7**
   Use SST # EN-50030



Note:
Engine at 90° ATDC.

7. Remove camshaft position (CMP) sensor

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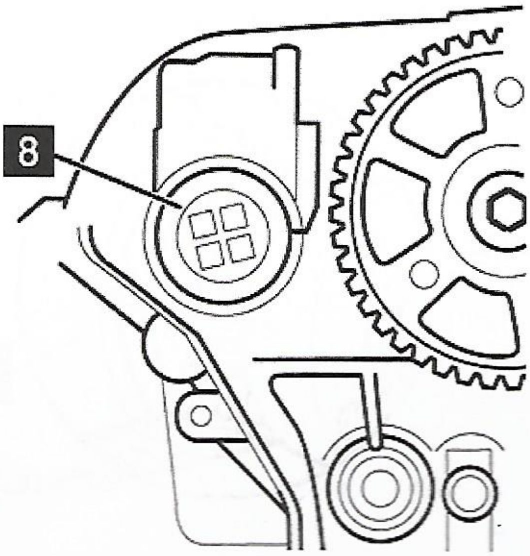
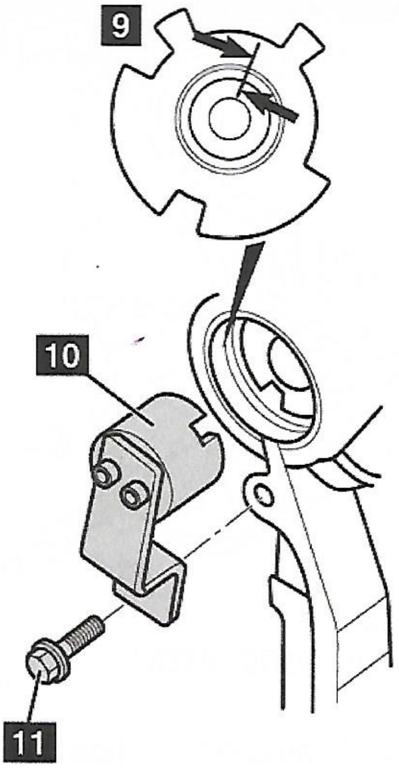
TIMING BELT continued...

8. Remove exhaust camshaft oil seal **8**

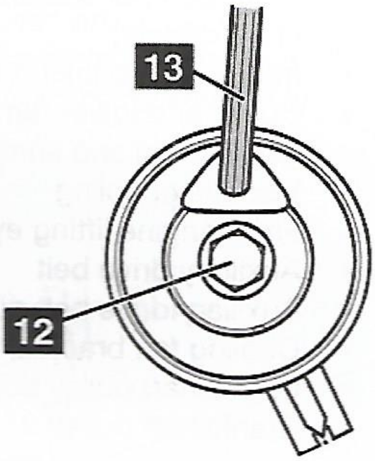


9. Mark camshaft reluctor and exhaust camshaft with paint or chalk where indicated **9**

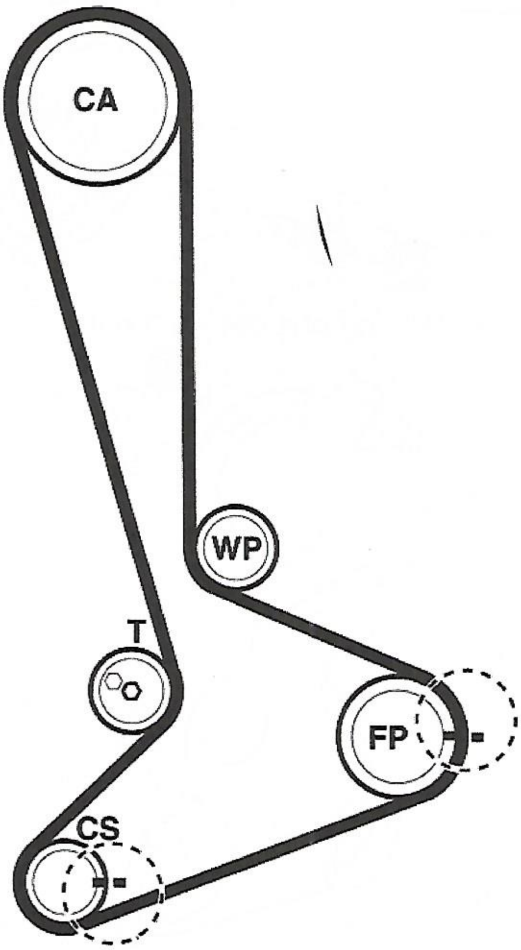


Caution:
Reluctor MUST NOT turn on camshaft!

10. Fit exhaust camshaft locking tool **10**, LVN & LWH **use** SST # EN-50029 LWN **use** SST # EN-51025 and secure with bolt **11**
11. Slacken tensioner pulley bolt **12**
12. Move tensioner pulley away from belt, use Allen key **13** and finger tighten bolt



13. Remove timing belt.

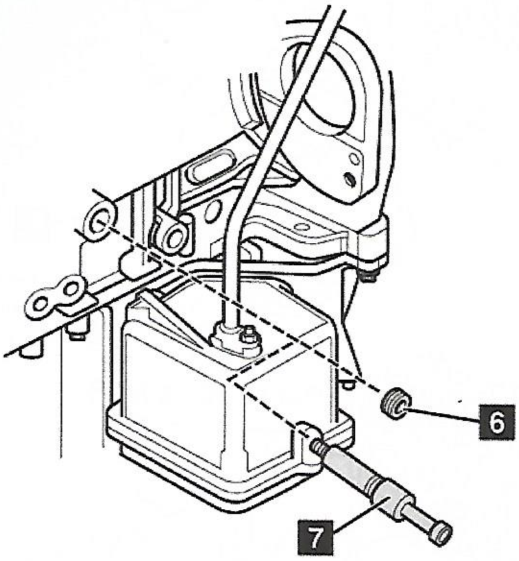


Images sourced from **AUTOPEDIA**, *powered by* ***Autodata***

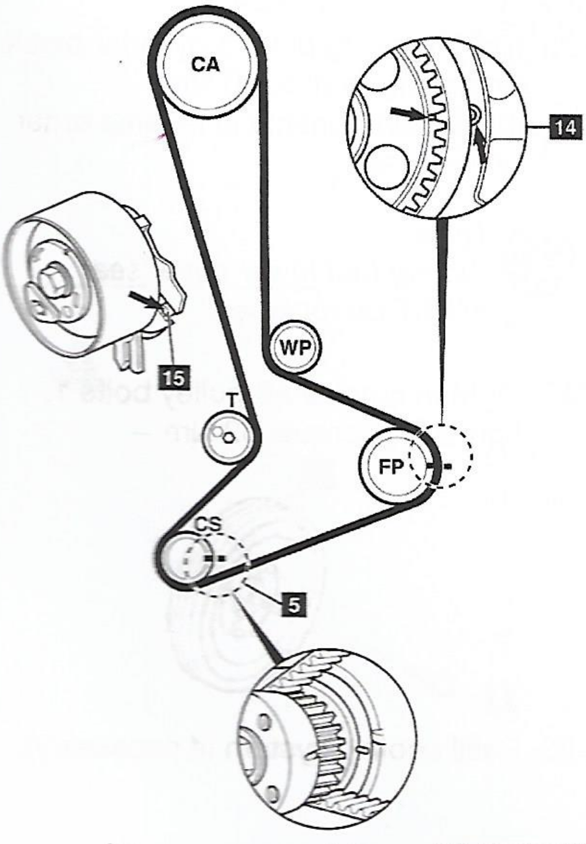
TIMING BELT continued...

Timing Belt Installation

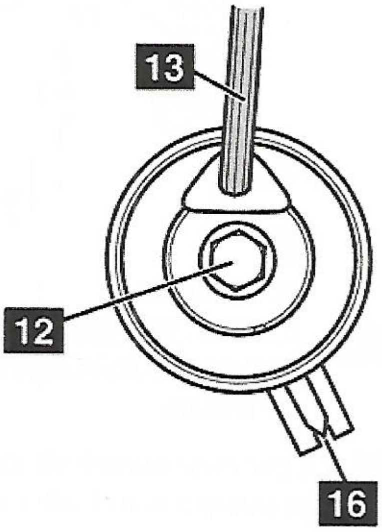
1. Ensure crankshaft sprocket timing marks at 3 o'clock position **5**
2. Ensure crankshaft locking tool located correctly **7**



3. Ensure exhaust camshaft locking tool located correctly **10**
4. Align high-pressure fuel pump sprocket timing marks **14**



5. Ensure tensioner pulley located correctly on dowel pin **15**
6. Fit timing belt in following order:
   - Crankshaft sprocket
   - High-pressure fuel pump sprocket
   - Water pump pulley
   - Inlet camshaft sprocket
   - Tensioner pulley
7. Turn tensioner pulley anti-clockwise until pointer aligned with notch **16**, use Allen key **13**
8. Tighten tensioner pulley bolt **12**, tightening torque: 28 Nm



9. Remove exhaust camshaft locking tool **10**
10. Ensure marks on exhaust camshaft and reluctor aligned **9**

⚠ *WARNING:*
Exhaust camshaft MUST be replaced if reluctor has turned on camshaft!

11. Remove crankshaft locking tool **7**
12. Turn crankshaft two turns clockwise to setting position
13. Ensure crankshaft sprocket timing marks at 3 o'clock position **5**
14. Fit crankshaft locking tool **7**

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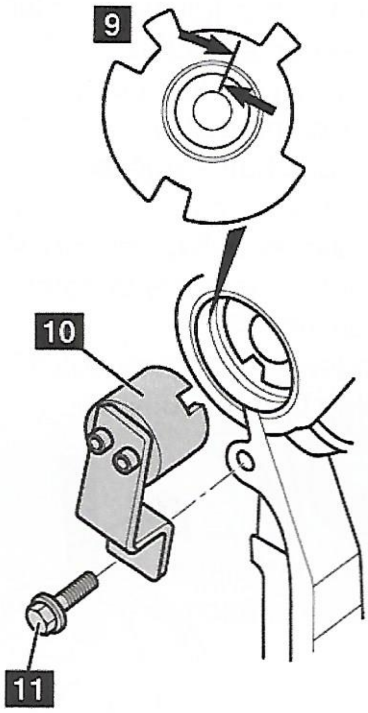
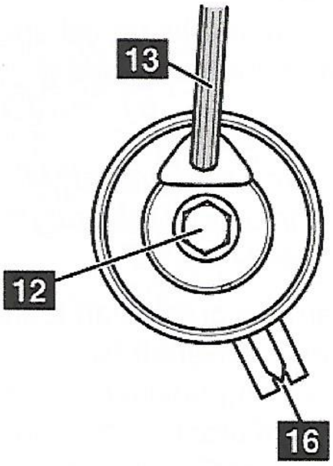
TIMING BELT continued...

15. Ensure marks on exhaust camshaft and reluctor aligned **9**



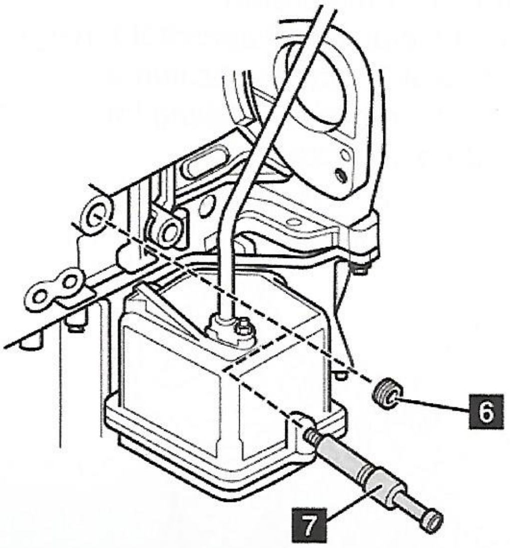
WARNING:
Exhaust camshaft MUST be replaced if reluctor has turned on camshaft!

16. Fit exhaust camshaft locking tool **10** and secure with bolt **11**
17. Ensure tensioner pulley pointer aligned with notch **16**

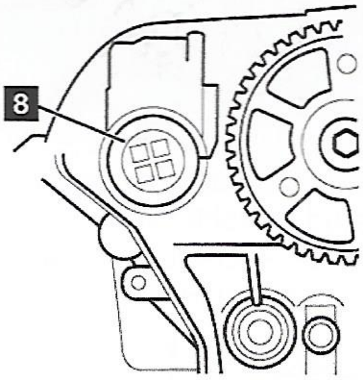


If not: Repeat tensioning procedure

18. Remove:
    - Camshaft locking tool **10**
    - Crankshaft locking tool **7**



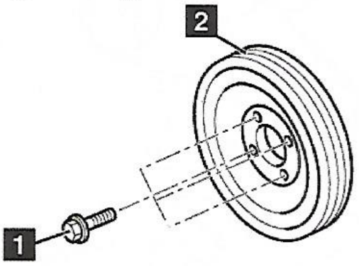
19. Fit new camshaft oil seal **8**



20. Refit blanking plug to cylinder block, tightening torque: 50 Nm
21. Install components in reverse order of removal

Note:
Timing belt lower cover seal MUST be replaced.

22. Tighten crankshaft pulley bolts **1**, tightening torque: 32 Nm



23. Refill cooling system (if necessary).

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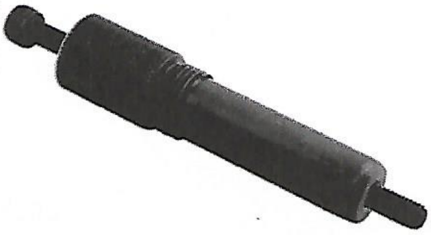
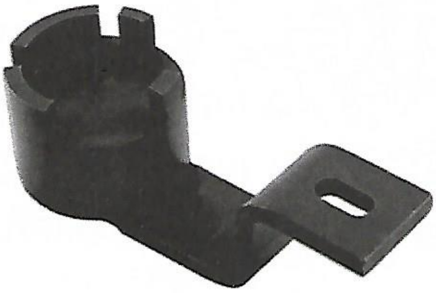
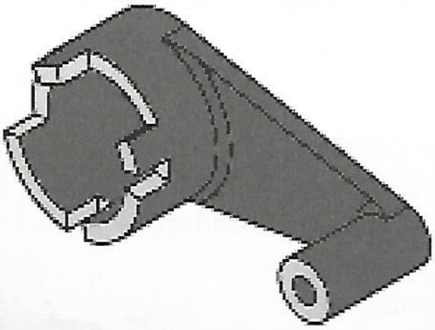
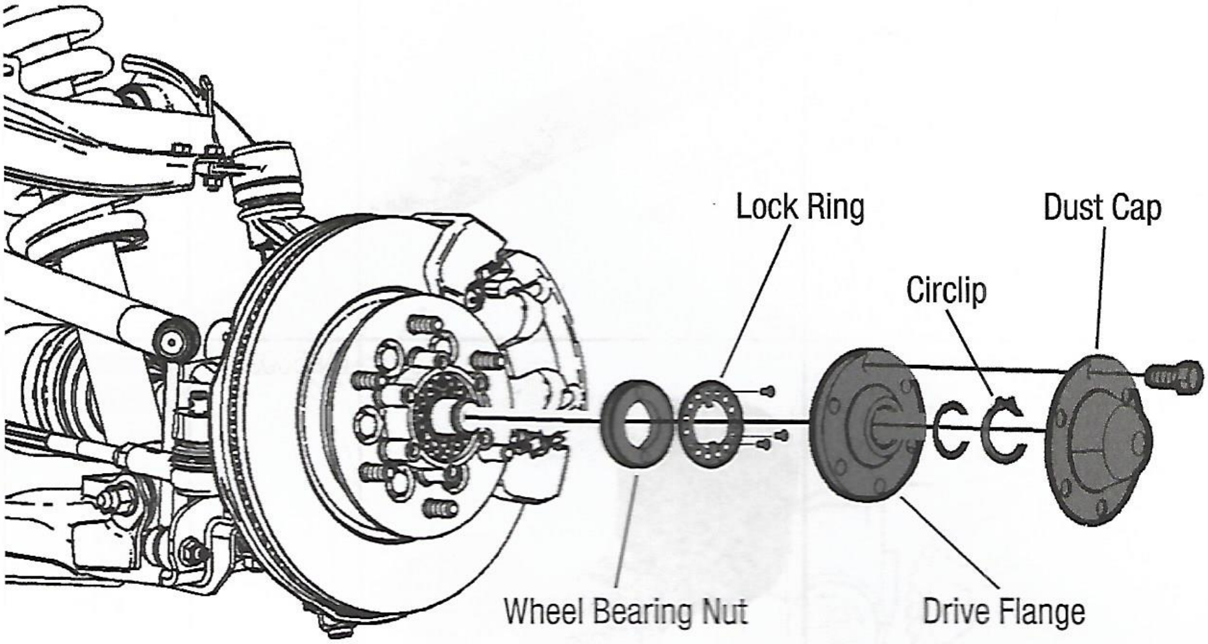
TIMING BELT continued...

Special Service Tools (SST's)			
Description	**Image**	**OEM SST #**	**Repco SST #**
Crankshaft Locking Tool		EN-50030	Included in kit ET4370
Exhaust Camshaft Locking Tool LVN & LWH engines (2012-13MY)		EN-50029	Included in kit ET4370
Exhaust Camshaft Locking Tool LWN engines (2014MY onwards)		EN-51025	ET4371

Caution: *The 2014MY saw the upgrade to the LWN engine and requires a new Exhaust Camshaft Timing Tool. Using the old tool will damage the reluctor and require the replacement of the camshaft to correct the damage!*

WHEEL BEARING REPACK

Like many four wheel drive vehicles the RG Colorado requires regular maintenance of the Front Wheel Bearings. The procedure is not dissimilar to that of similar vehicles.



You will need a two lug wheel bearing socket to remove and adjust the wheel bearing pre-load.

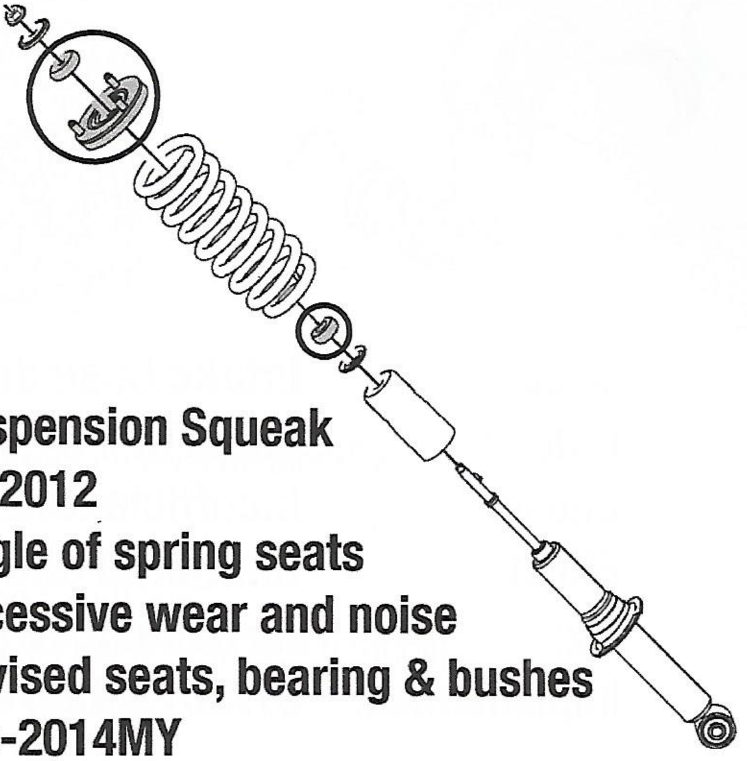
Installation Guide

1. When installing new bearings use the wheel bearing socket to tighten the bearing to 30Nm pre-load
2. Spin the disc rotor at least 10 rotations
3. Loosen the bearing retaining nut
4. Repeat two more times.
5. Apply a suitable sealant to the drive flange
6. Fit a new circlip (Holden states Circlip is single use)
7. Fit dust cap and torque to 59Nm.

Special Service Tools (SST's)			
Description	**Image**	**OEM SST #**	**Repco SST #**
Wheel Bearing Socket		CH-36827	TBA

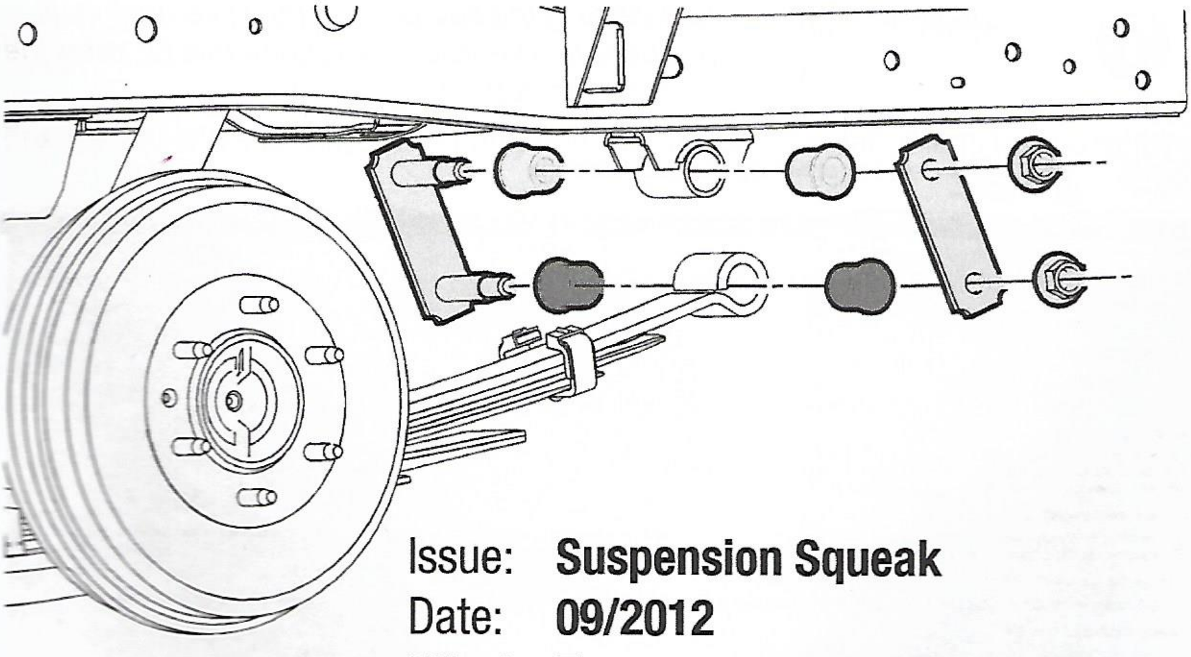
KNOWN ISSUES

Suspension Squeaks



Issue: **Suspension Squeak**
Date: **09/2012**
Cause: **Angle of spring seats**
Effect: **Excessive wear and noise**
Fix: **Revised seats, bearing & bushes**
Implemented: **pre-2014MY**

Modified parts circled

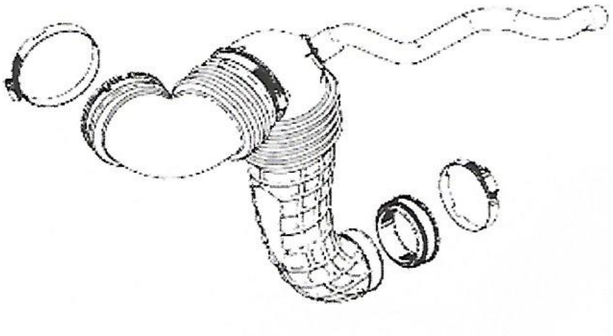


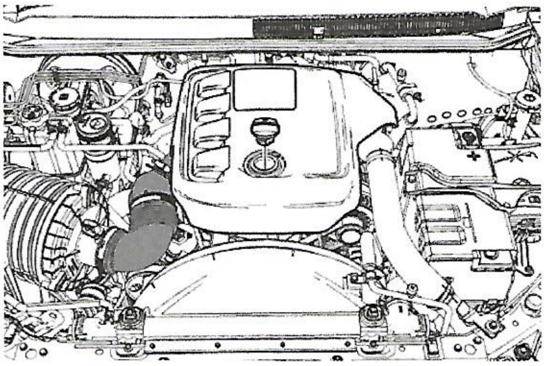
Issue: **Suspension Squeak**
Date: **09/2012**
Effect: **Excessive bush wear and noise**
Fix: **No fix, replace lower bushes!**

Bushes that suffer from wear shown in dark grey

KNOWN ISSUES continued...

Intake Hose Dislodging

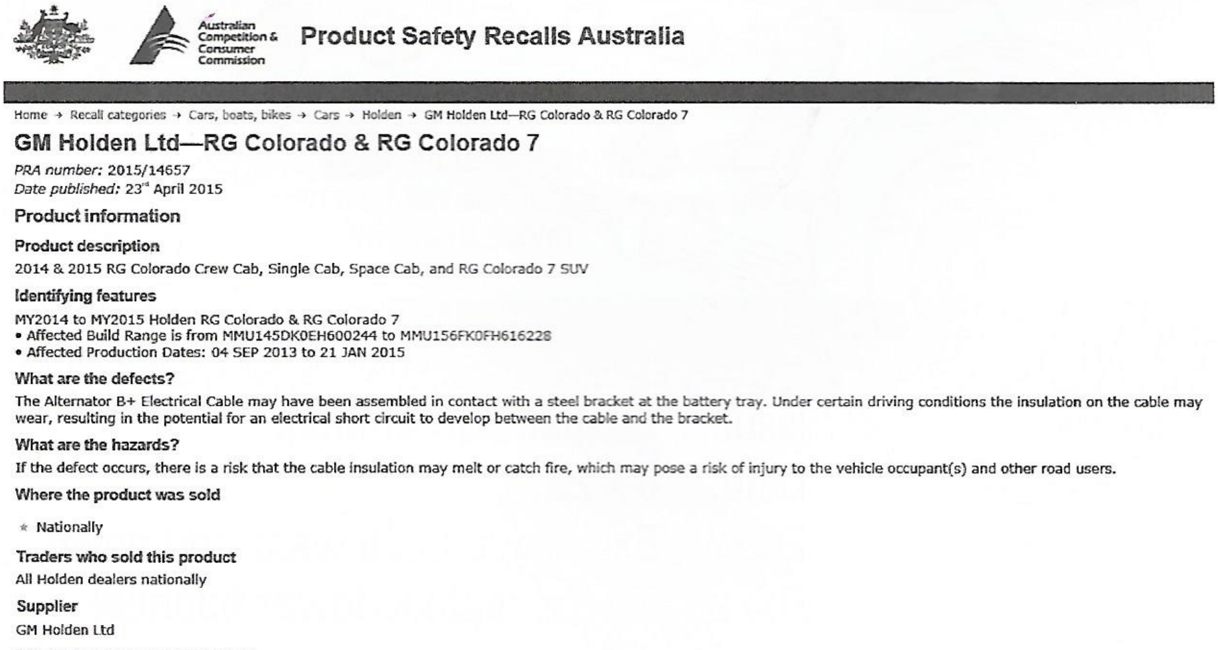




Issue: **Intake Hose dislodging**
Date: **09/2012**
Cause: **Insufficient fixing**
Effect: **Unfiltered and unmetered air**
Fix: **Revised hose (twice)**
Implemented: **07/2013 then 08/2013**

Alternator Wire Shorting Out

Note: *This issue is the subject of a recall campaign. If you believe a vehicle may require this fix, refer the owner to an authorised dealer!*



Australian Competition & Consumer Commission **Product Safety Recalls Australia**

Home → Recall categories → Cars, boats, bikes → Cars → Holden → GM Holden Ltd—RG Colorado & RG Colorado 7

GM Holden Ltd—RG Colorado & RG Colorado 7

PRA number: 2015/14657
Date published: 23rd April 2015

Product information

Product description

2014 & 2015 RG Colorado Crew Cab, Single Cab, Space Cab, and RG Colorado 7 SUV

Identifying features

MY2014 to MY2015 Holden RG Colorado & RG Colorado 7
- Affected Build Range is from MMU145DK0EH600244 to MMU156FK0FH616228
- Affected Production Dates: 04 SEP 2013 to 21 JAN 2015

What are the defects?

The Alternator B+ Electrical Cable may have been assembled in contact with a steel bracket at the battery tray. Under certain driving conditions the insulation on the cable may wear, resulting in the potential for an electrical short circuit to develop between the cable and the bracket.

What are the hazards?

If the defect occurs, there is a risk that the cable insulation may melt or catch fire, which may pose a risk of injury to the vehicle occupant(s) and other road users.

Where the product was sold

- Nationally

Traders who sold this product

All Holden dealers nationally

Supplier

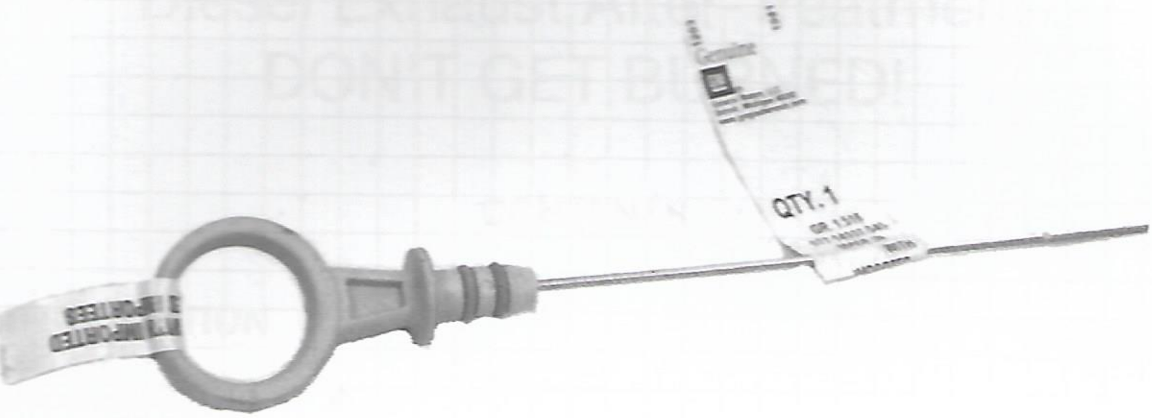
GM Holden Ltd

What should consumers do?

Holden will write to all affected customers to notify them of the required action.

KNOWN ISSUES continued...

Revised Engine Oil Dipstick

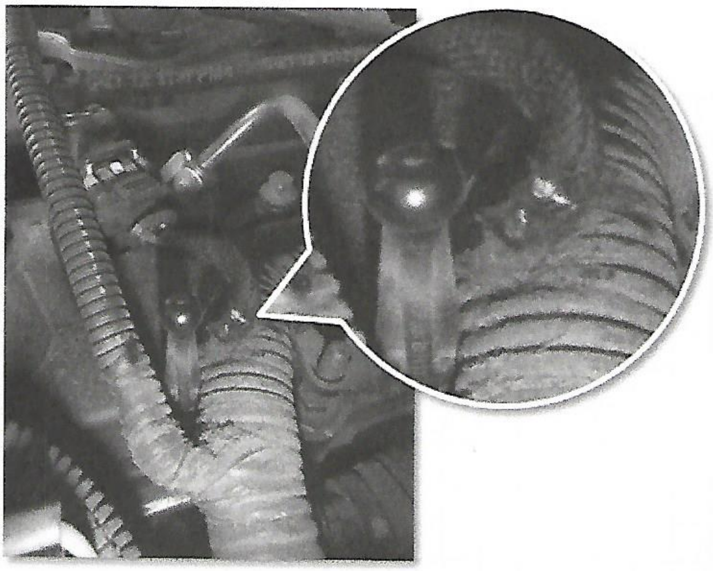


Issue:	**Incorrect oil level on dipstick**
Date:	**2015-16MY**
Cause:	**Change in dipstick**
Effect:	**Incorrect oil level**
Fix:	**Revised dipstick (2 blue 'o'rings)**
Bulletin #:	**TL2617-1512**

Injector Wire chafing

The wires to Cylinder #1 fuel injector had chafed through the outer and inner insulation of this vehicle. The wires had rubbed on the leg of the upper engine cover.

Ensure that wires (or any other components) are routed clear of legs before refitting.



Section ii

Diesel Exhaust After-Treatment
DON'T GET BURNED!

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INTRODUCTION

Overview

Diesel Exhaust After-Treatment (DEA) has the job of cleaning up all of the exhaust emissions that cannot be prevented in the combustion chamber. This includes all exhaust emissions devices:

- Diesel Oxidisation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- NOx Catalyst (Lean NOx Trap or LNT)
- Selective Catalyst Reduction (SCR)
- Hydrogen Sulphide (H2S) Catalyst

Note: *Exhaust Gas Recirculation (EGR) is not normally considered as an after-treatment, due to its effect being at the time of combustion rather than after!*

DEA systems can be used individually or in combinations. It is fair to say that as the emission laws have become increasingly stringent the need for such systems has become increasingly necessary. Early reports suggest that the implementation of EURO 6c which comes into effect in Europe in September 2017 will require all diesel vehicles to utilise a DOC, DPF & SCR (unless new technologies are developed to reduce emissions). For Australia and New Zealand, we'll see a gradual increase in these systems as they are added to meet European demand, but as yet there is no implementation date for the ADR equivelant of 6c at this stage.

Catalysts

All after-treatment processing requires a catalyst, its purpose is most easily described by its meaning...

> **Catalyst**
>
> / ’ kat(ə)lɪst /
>
> *noun*
>
> a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

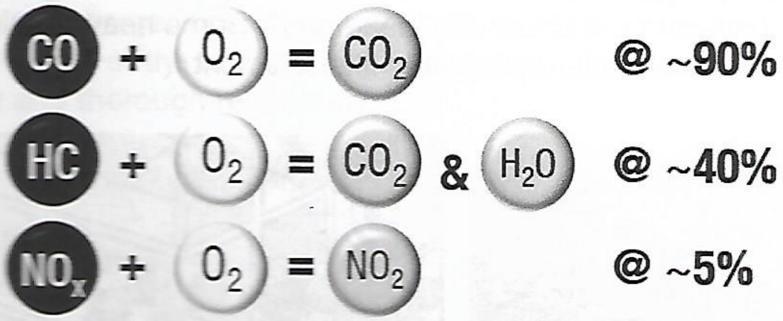
The catalysts used in DEA systems are usually made of ceramic monolith (but occasionally stainless steel spun mesh) which is coated with precious metals in a process called ‘washing’.

DIESEL OXIDISATION CATALYST (DOC)

Component Overview

The DOC is what most technicians will identify as a catalytic converter. Unlike modern unleaded vehicles which utilise a 3-way (meaning they create 3 chemical reactions), the DOC is a 2-way catalyst as it targets mainly the Carbon Monoxide (CO) and Hydrocarbons (HC).

The oxidisation catalyst consists of a ceramic substrate with a platinum wash coat. The following diagram shows the key chemical reactions and their efficiency (% of original emissions converted):



The DOC has four main functions:

- Reduce CO emissions
- Reduce HC emissions
- Create Nitrogen Dioxide (NO2) for DPF
- Generate the exhaust temperature required to facilitate DPF regeneration.

Note: *The optimal operating temperature for a DOC is 300°C, at higher temperatures CO & HC conversions improve slightly but causes Sulphates (SO4) which is converted in to Sulphuric Acid (H2SO4)!*

Servicing and Maintenance

The DOC does not require any servicing should last for the life of the vehicle

Note: *Life of vehicle is the true life (not just a term from the manufacturer) but is based on the requirement that the engine is always in perfect working order. Inaccurate air/fuel control or excessive oil consumption will cause damage to the component!*

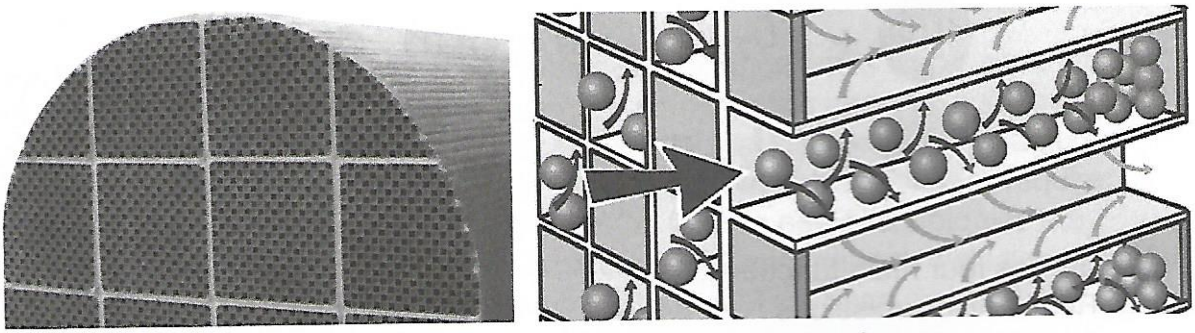
DIESEL PARTICULATE FILTER (DPF)

Component Overview

Diesel Particulate Filters are a common method used by manufacturers to meet the hydrocarbon limits of EURO V emissions on diesel vehicles and are capable of removing up to 100% of Particulate Matter (PM). They have been used on road vehicles in some parts of the world since 1996.

DPF Construction

The DPF core looks similar to a catalytic converter. It is made from a ceramic substrate; usually silicon carbide which has micro-porous walls. The core has alternate channels plugged which forces the gasses to flow through the wall and the particulates collect in the channel's "dead end". Some heavy vehicle DPF applications use a serviceable/replaceable filter element.



Typical DPF Substrate and how PM is trapped

DPF Operation

The trapped Particulate Matter in the DPF is monitored by the ECM by means of a Pressure Differential Sensor which monitors the difference in exhaust gas pressure before and after the DPF. The pressure differential is calculated by the ECM and is usually displayed in the Live Data menu of a compatible Scan Tool as an inferred value of grams (g).

In most fitments, the use of an Diesel Oxidisation Catalyst (DOC) upstream of the DPF is adopted to generate the exhaust temperatures required to initiate regeneration. Once the exhaust gases have heated the DPF substrate (filter) to a temperature of 650°C to 800°C regeneration will occur.

During regeneration the following chemical reaction occurs:

$$HC + NO_2 = CO_2 \;\&\; H_2O \quad @ >85\%$$

DIESEL PARTICULATE FILTER (DPF) continued...

Regeneration

Regeneration is the process of removing accumulated particles from the DPF. While in regeneration mode the ECM will do any number of the following to achieve the desired exhaust temperature:

- Restrict throttle opening to facilitate enrichment
- Cease EGR operation to increase combustion temperature
- Delay main fuel injection to further facilitate enrichment
- Commence post fuel injection, fuel is vaporised but not burnt in the cylinder. This vapour oxidises in the Oxidisation Catalyst creating the 650°C to 800°C exhaust gas temperatures required for regeneration
- Adjust turbocharger operation to maintain typical engine performance
- Throughout all of the above the ECM monitors it's input signals to maintain efficient and thorough regeneration.

There are 4 ways in which regeneration can occur (names will vary slightly between manufacturers):

- Passive Regeneration
- Active Regeneration
- Driver Initiated Regeneration
- Service Regeneration

The type of regeneration that occurs depends on the amount of Particulate Matter (PM) trapped in the DPF and the operating conditions of the vehicle.

Passive Regeneration

Passive Regeneration occurs whenever the vehicles normal operation brings the DPF substrate up to regeneration temperature (650°C to 800°C). In this operation there is no variation to vehicle operation and operator will be unaware that the regeneration has occurred.

Active Regeneration

For Active Regeneration to occur the amount of Particulate Matter trapped must be in the moderate range. Once the vehicle has completed all of the warm up criteria the ECM will control the fuel delivery post injections to send unburnt fuel down the exhaust system to the Oxidisation Catalyst where it ignites and creates the exhaust gas heat required to initiate regeneration. The ECM may also adjust idle speed and alter automatic gearshift timing (where applicable) to keep the engine speed up.

Note: *Some manufacturers will program the ECM to perform an Active Regeneration at a specified distance regardless of the amount of Particulate Matter trapped. Typically the ECM initiates an Active Regeneration if a successful regeneration has not been completed in the previous 1,000km!*

DIESEL PARTICULATE FILTER (DPF) continued...

Driver Initiated Regeneration

If the vehicle is not driven in a way that allows the DPF to regenerate fully, the trapped Particulate Matter will eventually reach the full range. If this occurs the ECM will alert the driver usually through indicator lamps and/or LCD display in the Instrument Cluster. The Owner's Manual will set out a specific drive cycle for the driver to complete. This usually requires an extended drive at speeds in excess of 80km/h and may also require this to be done in a lower gear ratio.

Caution: *If the Driver Initiated Regeneration request is ignored it may result in a Service Regeneration, these usually incur a charge to the owner of the vehicle!*

Service Regeneration

If the driver fails to perform the Driver Initiated Regeneration and the trapped Particulate Matter continues to build up, the ECM will force the vehicle to undergo a Service Regeneration. The reason forcing the vehicle to return to a workshop for the procedure is because the level of contamination is so high, a partial regeneration may render the DPF unserviceable. As with the Driver Initiated Regeneration the driver will be alerted through indicator lamps and/or LCD display in the Instrument Cluster.

Caution: *If the ECM registers a DPF contamination level in excess of its threshold it will prevent the vehicle from undergoing any form of regeneration. This is for three main reasons: Firstly, the amount of contamination is so great that regeneration would be unlikely to return the DPF to a serviceable condition and secondly, the amount of back pressure in the exhaust coupled with the engine load required to achieve regeneration could result in catastrophic engine damage and thirdly, the heat generated in the DPF from the combustion of the PM could exceed the safe operating range of the DPF and its heat shields!*

Note: *In most cases, the manufacturer will require the engine oil level to be inspected after a Service Regeneration. Some vehicles actually increase the oil pan level by around half a litre due to dilution from the addition of extra fuel injected during the Service Regeneration process!*
While some manufacturers require an oil and filter change after a service regeneration, others only require it if excessive dilution has occurred or if multiple regenerations have been run concurrently.

DIESEL PARTICULATE FILTER (DPF) continued...

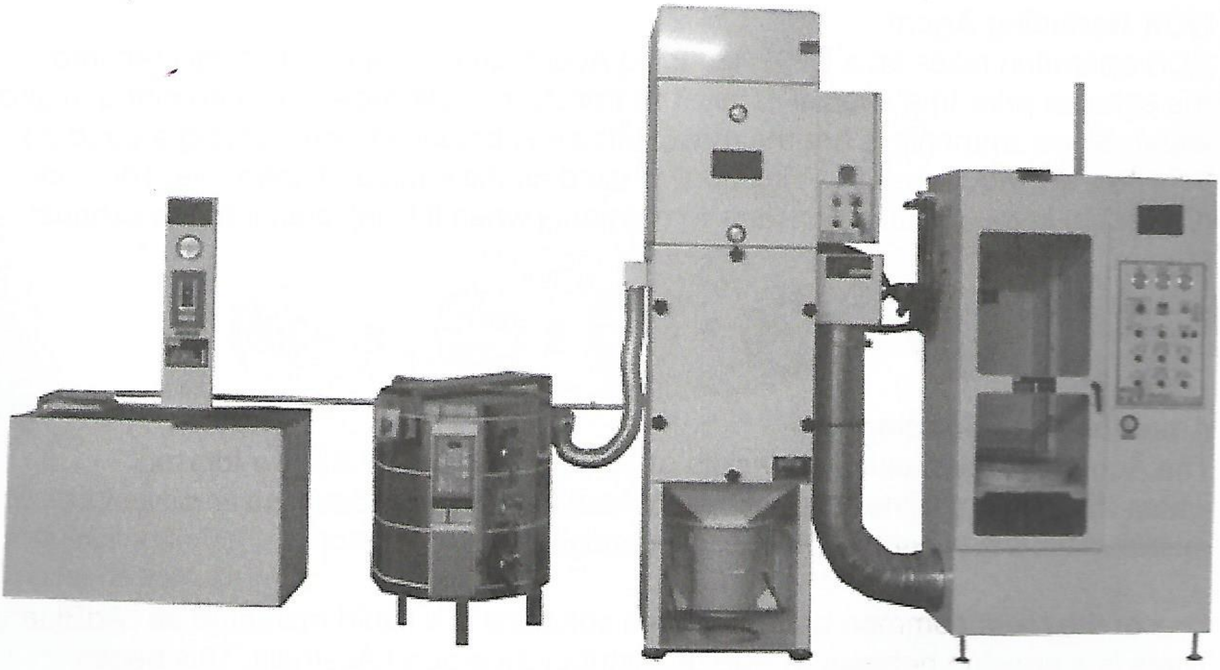
Servicing and Maintenance
There are no routine maintenance procedures required for light vehicle DPF's. However, after each regeneration occurs a small amount of ash remains trapped in the DPF substrate. After approximately 200,000km the DPF's ash loading will become excessive. This means that the tubes have been filled with non-combustible ash leaving no room for PM. When this occurs the manufacturer states that the DPF must be replaced.

As previously mentioned, heavy vehicles have DPF's that can be dismantled so that the ash can be extracted. Due to the high cost of replacement this has led to a number of companies offering light vehicle DPF servicing, where the DPF housing is cut open so that the substrate can be removed and placed in heavy vehicle servicing equipment. Once the substrate has been cleaned and checked it is refitted, the housing is welded closed and the component refitted to the vehicle.

Dissecting the DPF

Substrate removed

DPF reassembled



DPF maintenance equipment

Flow Testing *Thermal Regenerator* *Ash Collection* *Air Blaster*

SELECTIVE CATALYST REDUCTION (SCR)

Component Overview

One of the problems associated with Diesel engines is that in order to improve efficiency; thereby improving engine power, lowering fuel consumption and reducing emissions of Particulate Matter, the by-product of the higher combustion temperatures is an increase in the emission of oxides of nitrogen (NOX). Whilst High Pressure Exhaust Gas Recirculation has been used for many years to reduce NOX, this method is no longer desirable as it works against the general efficiency of an engine and every loss must be recouped.

SCR is a relatively simple and relatively low cost technology to reduce NOX in the exhaust pipe. It can yield reductions of up to 90%. The concept of SCR was patented in 1957 and has been developed and used in many industrial applications like stationary power plants and more recently ships, locomotives and motor vehicles.

When SCR is utilised the engine can be optimised for higher power output, low particulate matter emissions and low fuel consumption. The reduction of NOX is handled by after treatment in the exhaust pipe via the SCR catalyst. Most European truck makers are using SCR technology to meet EURO V exhaust emission requirements. These same vehicles are also on the roads here in Australia, with increasing numbers being equipped with SCR systems. Mercedes-Benz has been using SCR under the banner of 'BLUETEC' engine technology. Another popular Australian passenger car to utilise the SCR technology is the Mazda CX-7 fitted with the MZR-CD engine. Interestingly other models in the Mazda range that utilise the MZR-CD engine do not utilise the SCR System.

NOX Reducing Agent

SCR operation relies on a NOX Reducing Agent (ammonia) which is injected into the exhaust prior to a special catalyst to transform NOX molecules into nitrogen and water. Since ammonia is not the most suitable substance to be carrying around on vehicles, an "Aqueous Urea Solution" is used as the source of ammonia, The urea (CH4N2O) in the solution converts to ammonia when it is injected into the exhaust stream.

$$NO_x + \begin{matrix} CH_4 \\ N_2O \end{matrix} = N \; \& \; H_2O \quad @ \sim 90\%$$

Aqueous Urea Solution

The Aqueous Urea Solution consists of 32.5% Urea and 67.5% de-ionised water. It is non-toxic, non-flammable, colourless, usually odourless and must be manufactured to meet the DIN 70070 standard.

One of the most common brands of urea solutions is a liquid marketed as "AdBlue". There is a growing network of AdBlue distributors around Australia. This began initially through truck dealerships and workshops and now includes tie ups with several national fuel companies. Consumption for light vehicless is in the range of 0.5-1.2% by volume of diesel consumption.

SELECTIVE CATALYST REDUCTION (SCR) continued...

SCR System Layout

A tank contains the urea solution. A pump draws the urea solution from the tank and delivers it to the metering unit. The electronically controlled metering unit meters the urea solution into the mixer located in the exhaust stream. The SCR Catalyst is positioned downstream of the mixer.

SCR System Operation

The metering unit injects the urea solution into the exhaust flow prior to the SCR Catalyst. The urea solution mixes with the exhaust gases where it is converted into ammonia. In the SCR Catalyst, the ammonia reacts with the NOX, converting it to nitrogen and water.

If the urea solution tank is allowed to become empty or the incorrect specification liquid is used, the On Board Diagnostic (OBD) System will detect an increase in NOX and will illuminate a warning lamp. If the NOX is allowed to increase to approx. 5 g/kWh, the engine's ECM will record the data surrounding this event for later retrieval. If the fault remains and NOX levels increase to twice the limit (7 g/kWh), the ECM applies a 40% power reduction strategy. The loss of power is enough incentive to have the vehicle condition rectified.

In the projected EURO 6c emission standard further monitoring of the system is required ensure that the DEF is of the correct strength ratio, as the DEF depletes over time it is possible for the DEF to become 'stale' and ineffective. The use of a DEF sensor is one option that will monitor the urea quantity in the storage tank.

Mercedes-Benz has developed an AdBlue tank with a special filler neck that requires a dedicated nozzle to fill it. This ensures the tank does not get filled with diesel or petrol.

SELECTIVE CATALYST REDUCTION (SCR) continued...

Servicing and Maintenance
There appears to be two distinctly different service regimes which any vehicle might prescribe to:

- Workshop Based Servicing
- User Based Servicing

Workshop Based Servicing
Workshop based service systems have the topping up of the storage tank in the service schedule and usually have the filler that his hidden from view, if serviced and operating correctly the user won't ever have to top up the fluid. The following service procedure for the Mazda CX-7 is an example of Workshop Based Servicing.

User Based Servicing
User based service systems have the storage tank filler in an easily accessible position (such as alongside the fuel filler) and do not have the filling of the storage tank in the service schedule. The following service procedure for the Audi Q3 is an example of User Based Servicing.

Caution: *Diesel Exhaust Fluid (DEF) is non-hazardous. However, if spilt over time the reducing agent will evaporate leaving acidic urea salts that can damage paint & concrete!*

DEF in luggage area

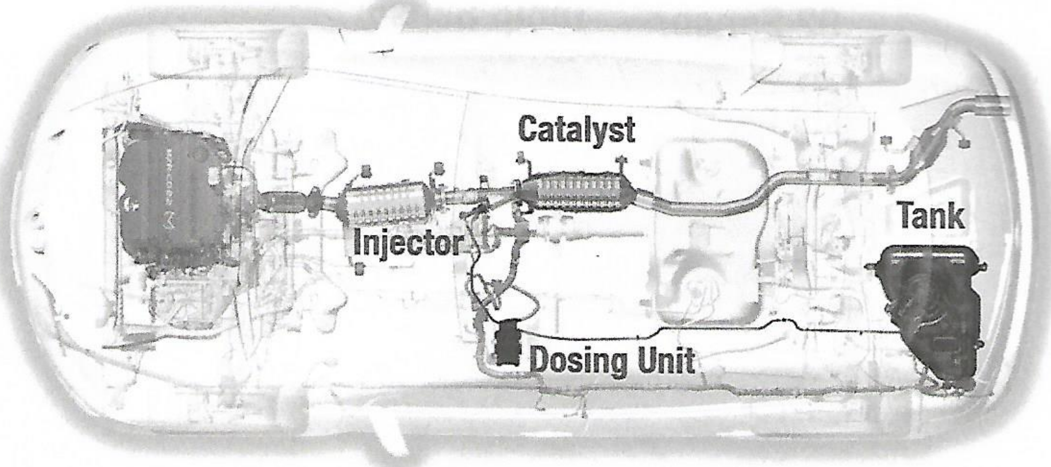
DEF in seat seams

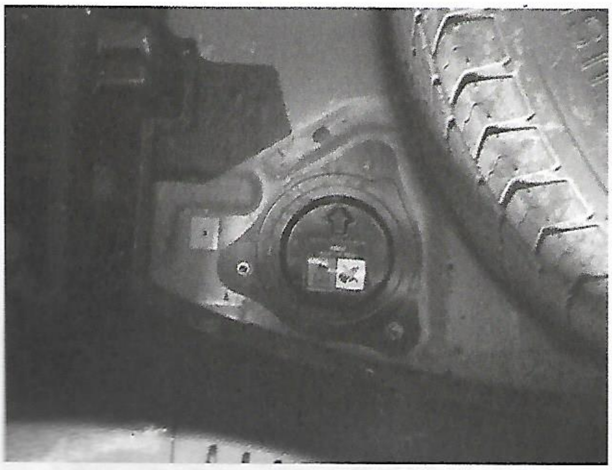
Damage to concrete floor

SELECTIVE CATALYST REDUCTION (SCR) continued...

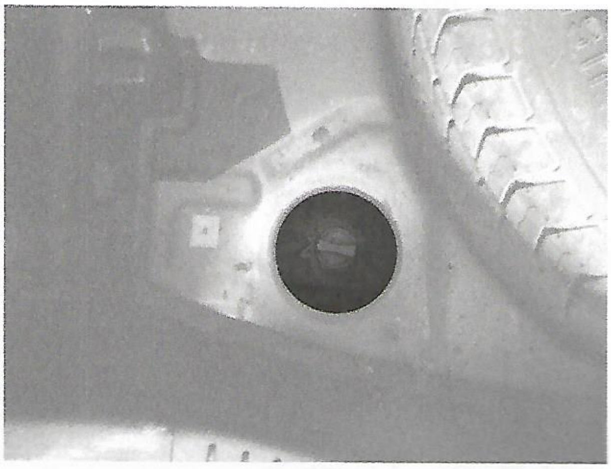
Mazda CX-7

Component Locations



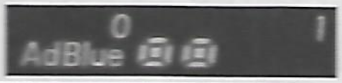
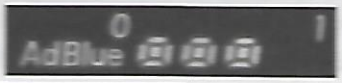


Spare Wheel Well



Tank Filler

Service Schedule

Schedule	Note	Procedure
20,000km / 12 Months	Tank capacity is 15.5 Litres	Top up DEF reservoir
40,000km / 24 Months	DEF level 1/2 or less 	Top up DEF reservoir
	DEF level 3/4 or more 	Drain out old DEF and refill with new fluid.

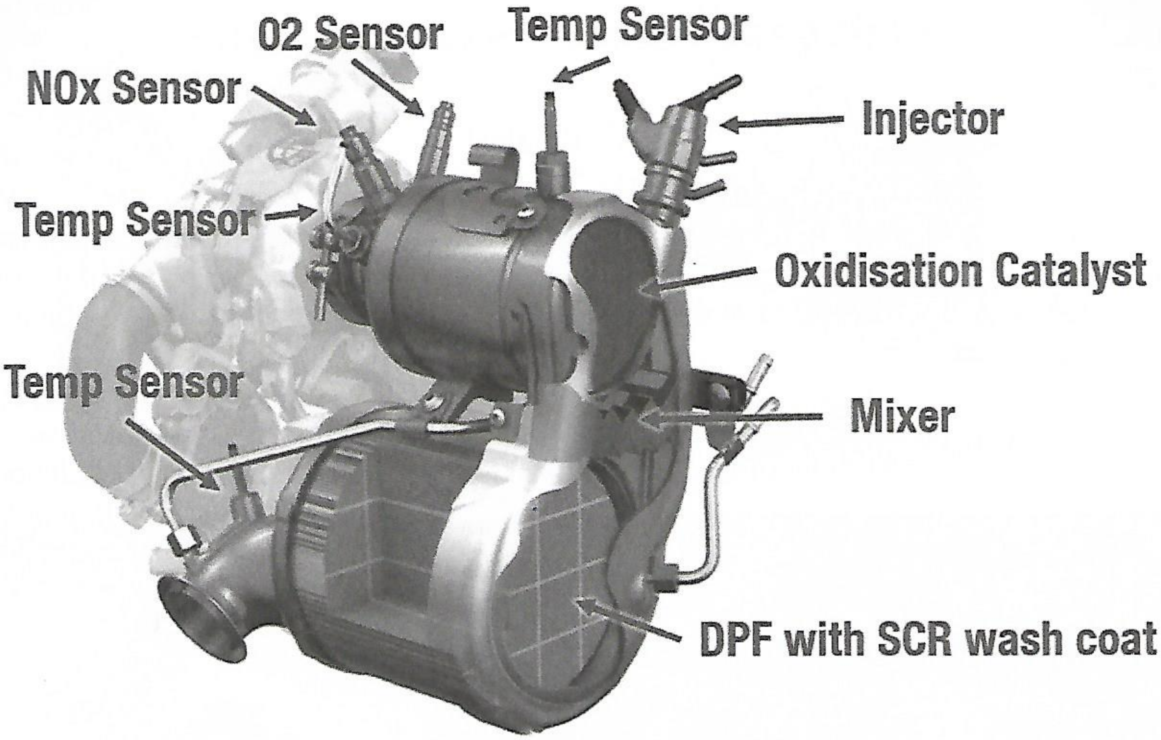
Note:

AdBlue gauge takes about 1 minute of driving at above 10km/h before it will reset.
This allows the control module sufficient time to monitor the NOx sensor to confirm that the correct fluid has been added!

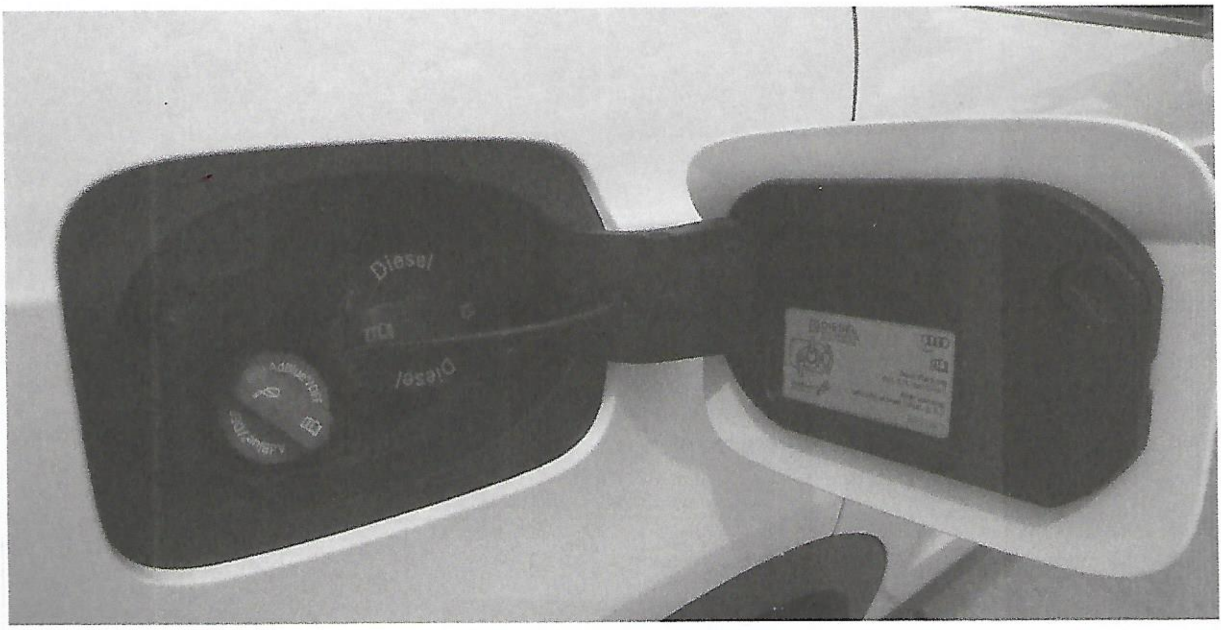
SELECTIVE CATALYST REDUCTION (SCR) continued...

Audi Q3

Component Locations


02 Sensor
Temp Sensor
NOx Sensor
Injector
Temp Sensor
Oxidisation Catalyst
Temp Sensor
Mixer
DPF with SCR wash coat

The DEA System is located on the back of the engine


Diesel
Diesel

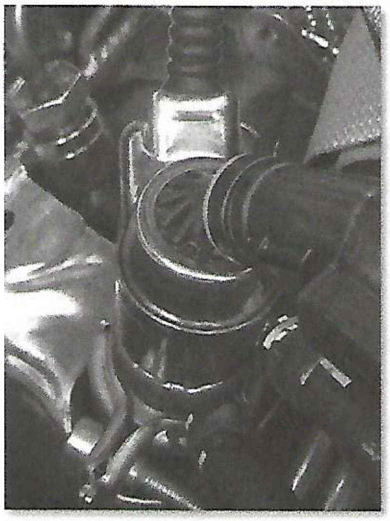
The DEF fluid filler is located adjacent to the fuel filler (Audi Q3)

Service Schedule

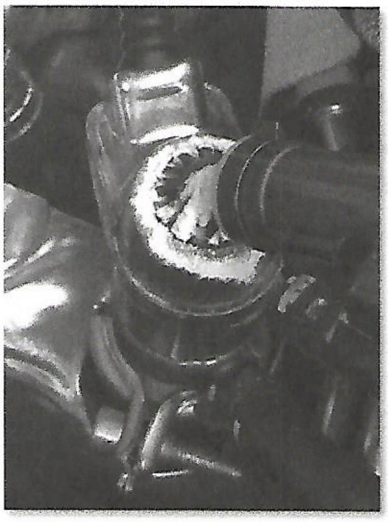
Schedule	Note	Procedure
48 Months	If DEF has not been topped up in 4 years	Drain out old DEF and refill with new fluid.

SELECTIVE CATALYST REDUCTION (SCR) continued...

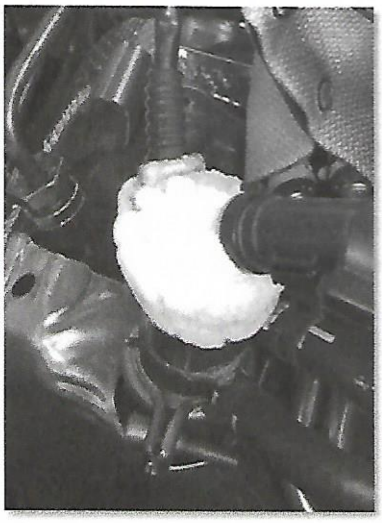
Diagnostic Tip
When it comes to leak diagnosis, following the trail of crystals will normally lead to the fault.



New



After 160km



Few days later...

Inspection Procedure

- The fluid can/will travel through the inside of sheathing on harnesses and piping
- Clean off crystal with warm water and bi-carb soda (2 tablespoons per 10L)
- Use shop air to dry thoroughly
- Start engine and watch for the formation of new crystals
- On hot components such as the injector they will appear quickly.

NOX CATALYST (LEAN NOX TRAP OR LNT)

The Oxides of Nitrogen (NOx) Catalyst is a simplified alternative to Selective Catalyst Reduction (SCR) that has been successfully used on stationary engines in power stations and other similar uses. It has had less success in light vehicles applications and is part of the emission system of VW vehicles that have been implicated in the "Defeat Device" scandal.

The NOx Catalyst has a wash coat of Zeolites or Barium which create a porous sponge like coating over the substrate. Although they are created naturally, engineered synthetic zeolites can be designed to capture only specific ions. As NOx ions pass the substrate they are trapped by the washcoat, unfortunately Sulphur Oxide (SOx) are very similar to NOx and are also trapped.

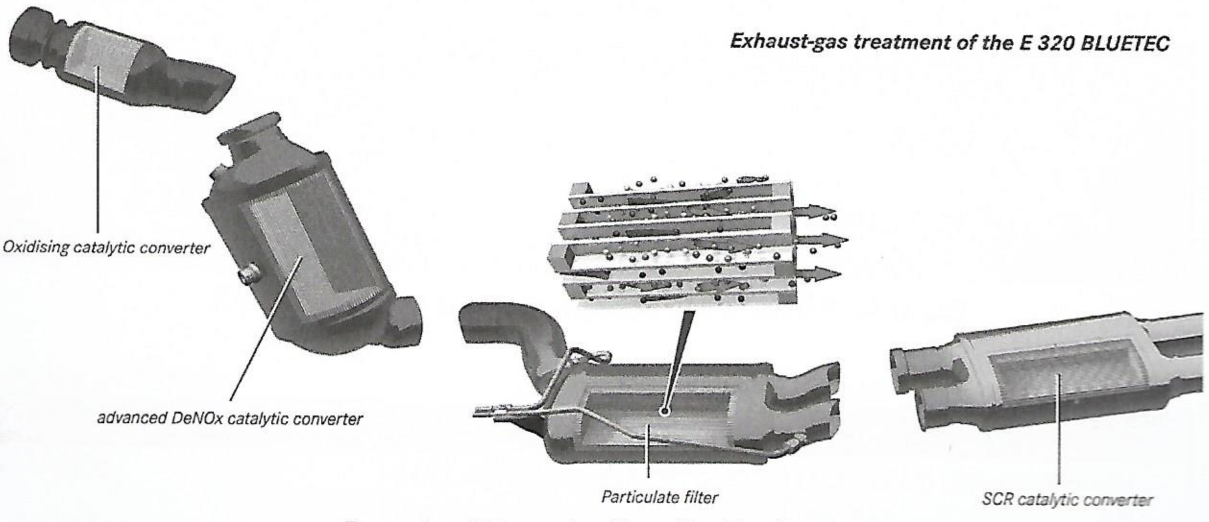
Once the NOx catalyst becomes soaked, the ECM will regenerate the catalyst by introducing Hydrocarbons (HC) in the form of un-burnt diesel fuel which increases the catalyst temperature to between 200-600°C and converts the NOx to Nitrogen and Water.

$$NO_x + HC = N \; \& \; H_2O$$

After several regenerations the NOx Catalyst becomes soaked with SOx which requires a regeneration temperature between over 620°C (often over 800°C).

Mercedes Benz application

The adoption of the NOx Catalayst in 'BlueTec' vehicles is not an alternative to SCR, but an assistant during cold temperatures. Because SCR does not operate from cold start the NOx Catalyst is used to trap the NOx until the desired exhaust temperature is achieved. In this application the NOx Catalyst is only used to hold the NOx and not convert it. Once the SCR is functional the HC rich exhaust stream draws the NOx from the Zeolites in a process known as desorbing (the opposite of absorb).


Exhaust-gas treatment of the E 320 BLUETEC
Oxidising catalytic converter
advanced DeNOx catalytic converter
Particulate filter
SCR catalytic converter

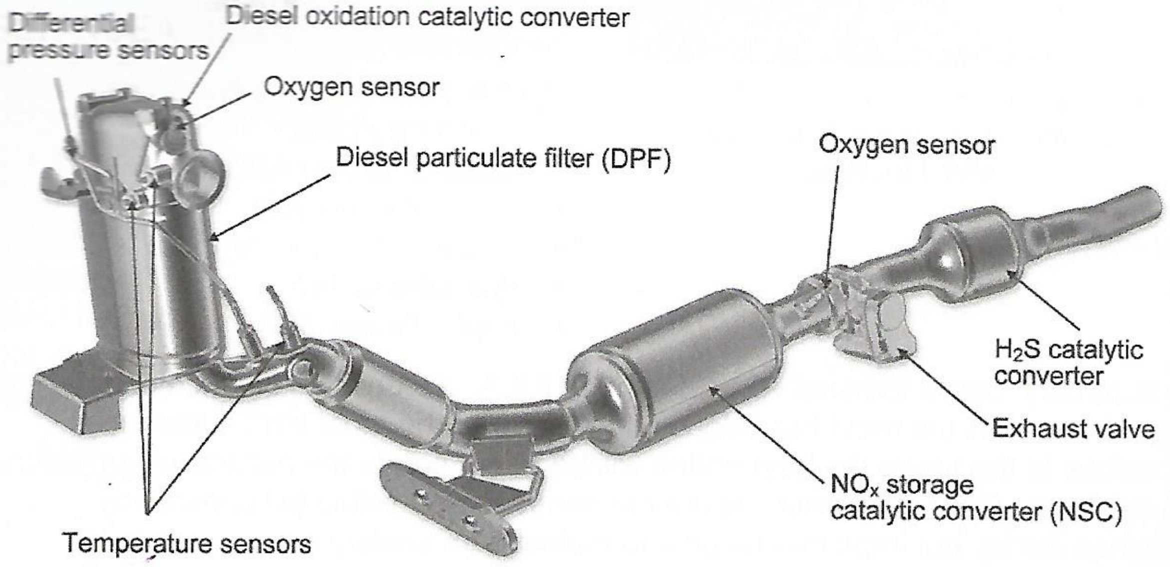
Example of Mercedes Benz BlueTec System

HYDROGEN SULPHIDE (H2S) CATALYST

The H2S Catalyst is required on vehicles that use a NOx Catalyst as an alternative to Selective Catalyst Reduction (SCR). When the NOx trap is purged of Sulphur Oxide (SOx) it creates small amounts of the highly undesirable Hydrogen Sulphide (H2S), commonly known as "Rotten Egg Gas". H2S is heavier than air, very poisonous, corrosive, flammable, and even explosive.

At temperatures above 300°C and at a lambda values between 0.9-1.1 the H2S Catalyst will convert the H2S into Sulphur Dioxide (SO2) and Water.

$H2S + O_2 = SO_2$ & H_2O @ ~100%

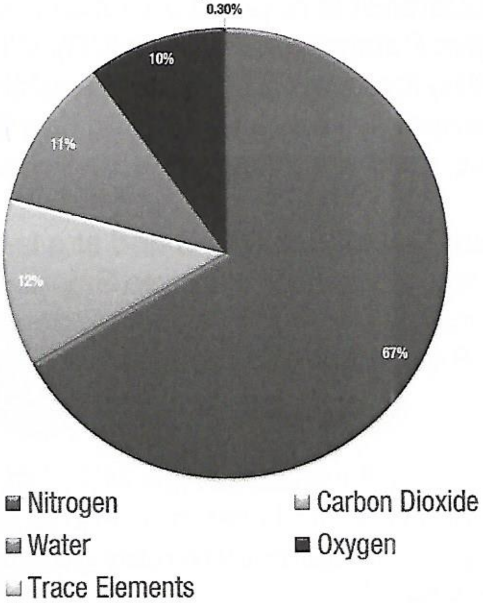

Differential pressure sensors
Diesel oxidation catalytic converter
Oxygen sensor
Diesel particulate filter (DPF)
Oxygen sensor
H_2S catalytic converter
Exhaust valve
NO_x storage catalytic converter (NSC)
Temperature sensors

Example of Volkswagen AG DEA system

SO2 is not a desirable emission as it is still poisonous to humans. However unlike H2S it is not absorbed through the skin and it is highly irritating to the eyes and throat of humans. Making it less insidious.

SUMMARY

Tailpipe of Mazda CX-7 with DOC, DPF & SCR shows no signs of any contaminants after 110,000km



Graph of typical emissions from a 'clean' diesel
Trace elements include:

- *Oxides of Nitrogen (NOx)*
- *Carbon Monoxide (CO)*
- *Particulate MATTER (PM)*
- *Hydrocarbons (HC)*
- *Sulphur Dioxide (S02)*

In summary, Diesel Exhaust After-Treatment (DEA) is a delicate balance of catalysts used to convert the most hazardous emissions into the most inert substances possible. In the future the best option will be to not create the hazardous emissions to start with. Current alternatives are not commercially viable (all conspiracy theories aside), but implementation into mainstream society is on the horizon.

As Nitrogen, Oxygen and Water are found in abundance in the Earths atmosphere, these elements are of little concern. However, Carbon Dioxide although not poisonous, is now known to be the leading cause of green house gas emissions and global warming and the largest majority comes from the transport industry.

The reduction of Carbon Dioxide can only be achieved by the reduction in fuel consumption (or find alternative ways to power a vehicle)! For 2015 the EU required a fleet wide limit of 130g CO2/km for passenger cars. As CO2 production is directly linked to fuel consumption this equates to an average fuel economy of 4.9L/100km.

Future fleet wide CO2 limits:

Region	Legislation Year	Carbon Dioxide (CO2)	Diesel consumption
Europe	2021	95g CO2/km	3.6L/100km
United States of America	2025	101g CO2/km	3.8L/100km
Australia	2025*	105g CO2/km	4.0L/100km

*currently only a recommendation by the Climate Change Authority.

Section iii

Suction Control Valve Advanced Diagnostics

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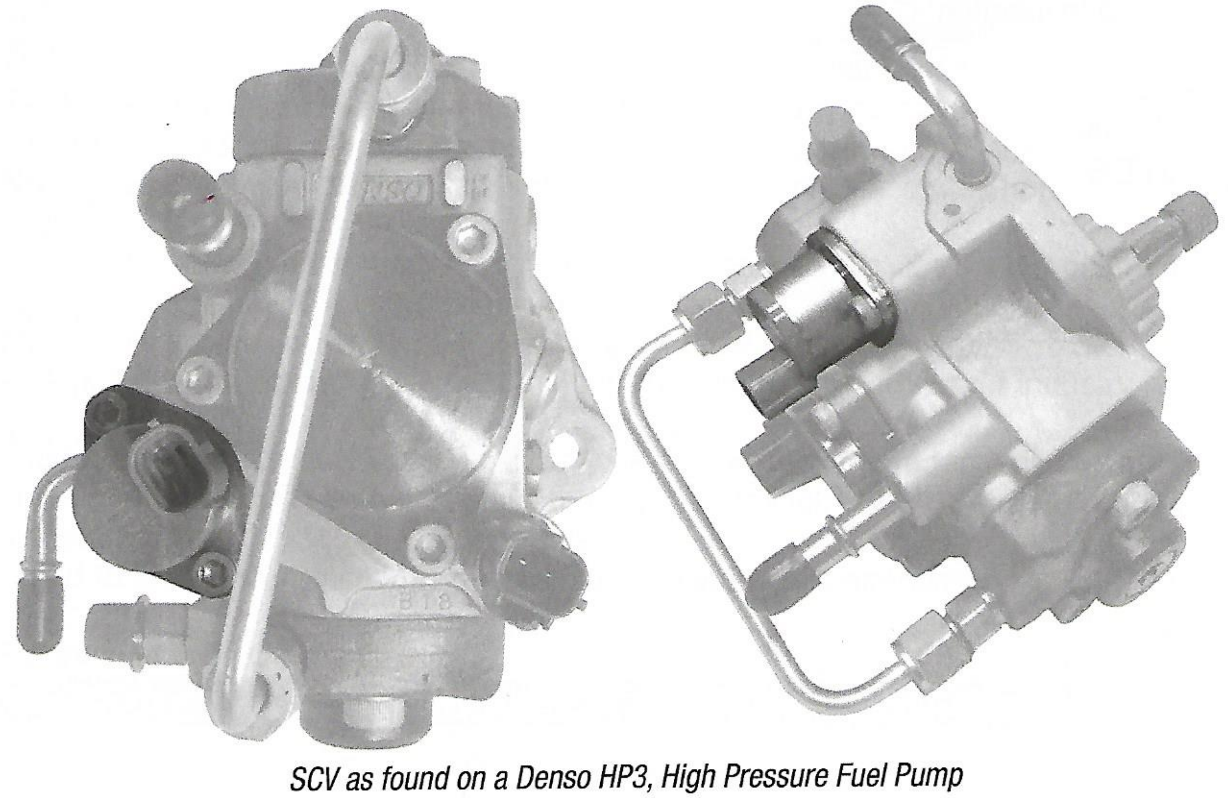
INTRODUCTION

The Suction Control Valve (SCV) is used by the ECM to control the amount of fuel entering the High Pressure Fuel Pump, this in turn controls the pressure of the fuel entering the Fuel (Common) Rail. The ECM uses a Pulse Width Modulated (PWM) Duty Cycle to control the solenoid while the Fuel Rail Pressure provides a feedback signal to allow the ECM to confirm that the desired output was achieved.
The Fuel Metering Valves are typically located on the inlet (low pressure) side of the High Pressure Fuel Pump.

There are a number of names used by different manufacturers for the SCV. With this particular component the name varies so often that it was hard to choose a universal name. Some manufacturers also have difficulty settling on which name to choose and refer to this component by numerous names throughout the vehicles diagnostic information. The following are some of the names used:

- Fuel Metering Valve
- Fuel Pressure Regulator
- Fuel Quantity Regulator
- Fuel Rail Pressure Regulator
- Inlet Metering Valve
- Pressure Control Valve
- Pressure Regulator Valve
- Spill Control Valve
- Volume Control Valve



SCV as found on a Denso HP3, High Pressure Fuel Pump

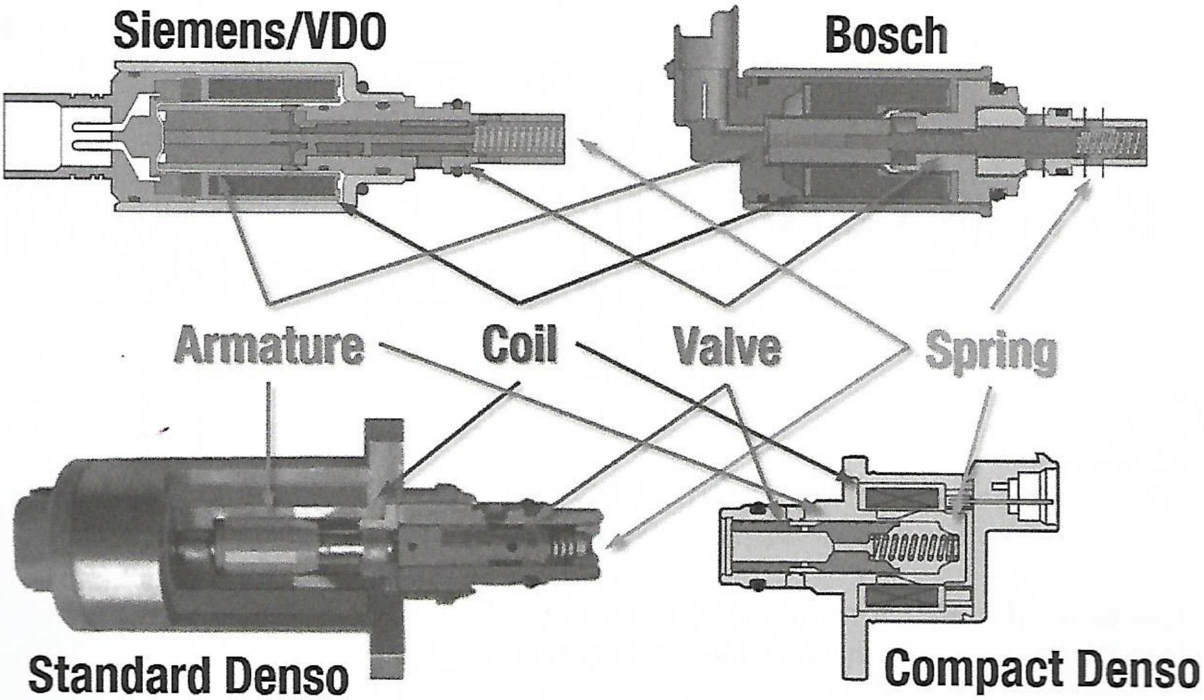
FUNCTION

The key functions and benefits of the SCV are listed below, detailed descriptions follow the list:

- Controls HPFP output by controlling fuel input
- Less energy to control low fuel pressure
- Reduce pump load
- Reduce heat generation
- Improves engine performance

At full output the HPFP draws approximately 15kW from the engine, by controlling the fuel input the load on the engine can be reduced by up to 70% (if the SCV duty cycle is 30% ON then it is 70% OFF and drawing minimal load). Along with a reduction in effort by the HPFP comes a reduction in heat generated that would otherwise heat the fuel. The Suction Control Valve (SCV) is continually adjusted by the PCM using duty cycle control.

Despite the varying manufacturers and names all SCV's are of the same basic design and operate under the same principles:

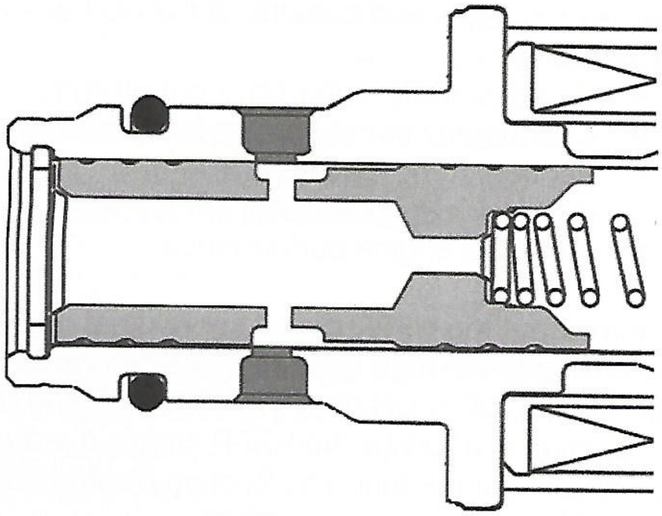


Comparison of SCV design

The SCV can be used in either a Normally Open or Normally Closed configuration. The choice of configuration is usually subject to the design of the engine and fuel system. The command chosen will be the one that requires the least ON time as this reduces the current draw on the ECM.

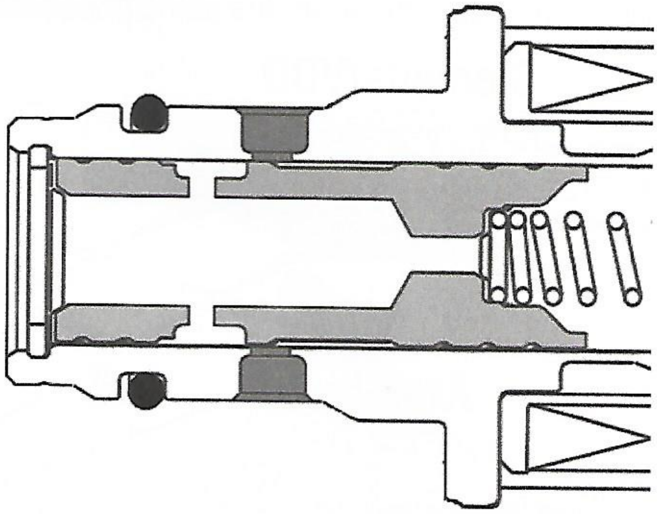
FUNCTION continued...

Normally OPEN



The alignment of the ports can easily be seen in this cross-section of a Normally OPEN SCV (Denso Compact SCV in this example)

Normally CLOSED



In this cross-section of a Normally CLOSED SCV, the piston is fully seated in it's rest position and the ports are closed (Denso Compact SCV in this example)

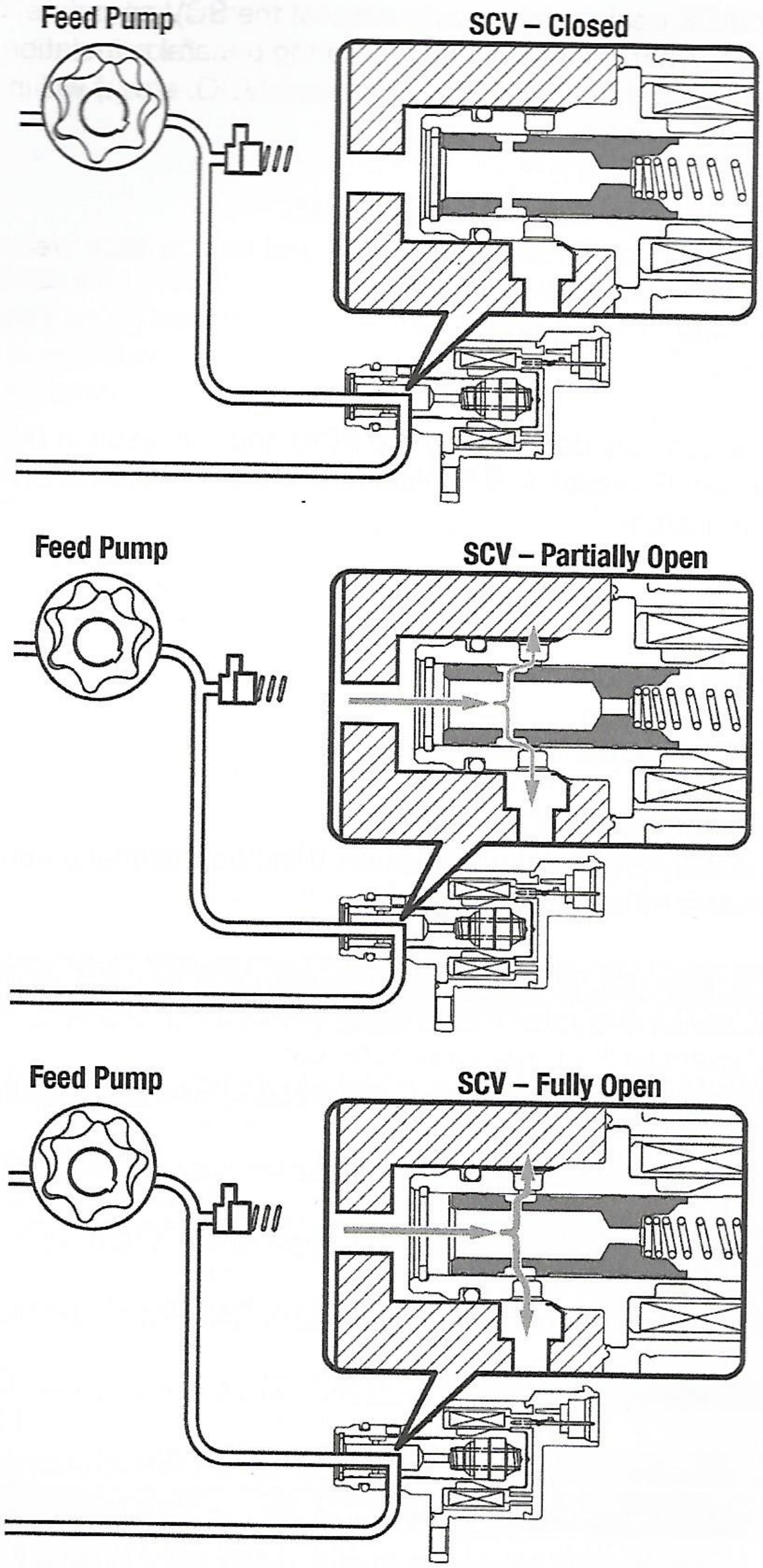
How to tell if a SCV is normally open or closed
(This information is rarely stated the factory manual)

1. Monitor the Rail Pressure and SCV Duty Cycle
- If Duty Cycle ON increases with Rail Pressure the SCV is Normally CLOSED
- If Duty Cycle ON decreases while Rail Pressure increases the SCV is Normally OPEN

2. With engine OFF disconnect the SCV:
- If engine starts, SCV is normally OPEN
- If engine doesn't start then SCV in normally CLOSED

FUNCTION continued...

SCV Fuel Flow


Feed Pump
SCV – Closed
Feed Pump
SCV – Partially Open
Feed Pump
SCV – Fully Open

The three diagrams (above) show the varying piston position and fuel flow (Denso Normally CLOSED Compact SCV in this example)

SERVICEABILITY

What is not often understood is that the SCV is proving to have a shorter service life than most fuel injectors. In many cases the SCV is not available through aftermarket parts retailers and OE dealers will usually only list the SCV complete with the HPFP at a huge expense. What is largely unknown to the general population is that the component manufacturer (Denso, Bosch, Siemens/VDO, etc…) will in most cases supply the SCV as a separate component.

DIAGNOSIS

There are a few ways to diagnose a faulty SCV and test for SCV wear.

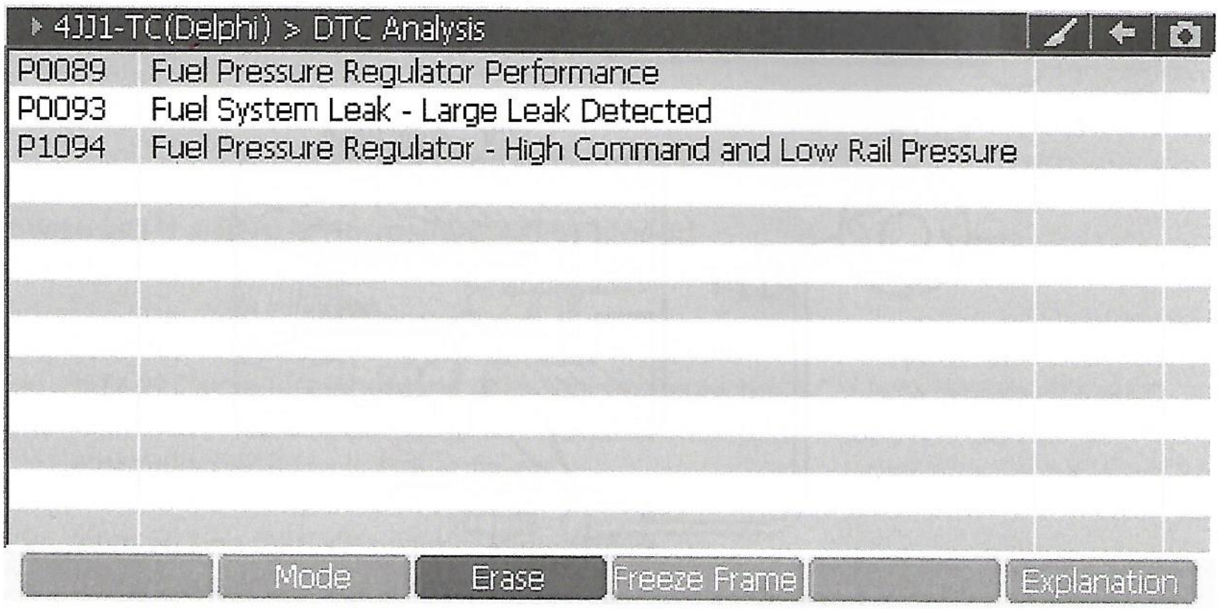
- Diagnostic Trouble Code (DTC)
- Scan Tool Data
- Oscilloscope

Solenoid failure is normally detected by the PCM and will result in DTC's and/or no start condition. However, mechanical failure will not. Typical symptoms of mechanical failure include:

- No Start
- Lean condition
- Rich condition
- Unstable fuel pressure
- Intermittent operation
- May log DTC's related to rail pressure

Diagnostic Trouble Code (DTC)

Scan Tools will usually provide DTC feedback if the operational parameters exceed desired fuel pressure thresholds.



4JJ1-TC(Delphi) > DTC Analysis

P0089	Fuel Pressure Regulator Performance
P0093	Fuel System Leak - Large Leak Detected
P1094	Fuel Pressure Regulator - High Command and Low Rail Pressure

Example of DTC's logged on an Isuzu D-Max with a faulty SCV

Note: *Some systems refer to the SCV simply as High Pressure Fuel Pump!*

DIAGNOSIS continued...

Scan Tool Data

Scan Tool Data can be of assistance, but usually only in the most severe cases where the SCV is sticking (and these instances usually trigger a DTC). Some vehicles have a Scan Tool Data parameter for SCV current, however this is not a live value and is subjected to averaging and displayed with a delay making it inaccurate.

Oscilloscope

Using an oscilloscope to monitor a specific circuit allows the operator to see the actual commands being sent to a component and/or the signals being sent back to the ECM. It is one way of examining the actual operation of a circuit without the Scan Tools interpretation.

In the diagnostic procedure for inspecting the SCV there are three values that are best monitored, so a three or more channel scope is preferred:

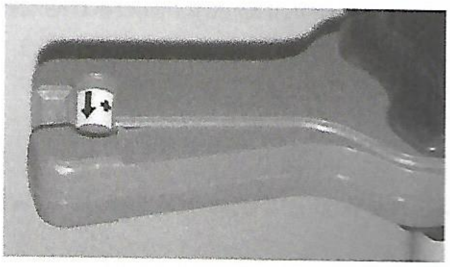
- Fuel Rail Pressure
- SCV Command Voltage
- SCV Current Draw

Connecting the Oscilloscope

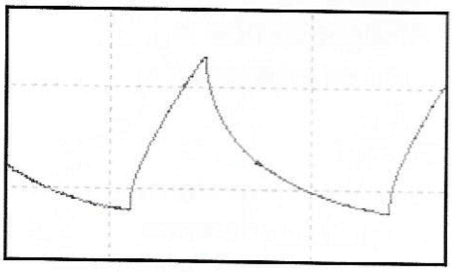
When it comes to connecting the oscilloscope probes, you can go to the trouble of tracking down ECM wiring and/circuit diagrams and if you do wish to do this the two circuits that you are looking for are the Suction Control Valve Command (SCV+) and the Fuel Rail Pressure Signal (FRPS). However, there is no need to go to this effort because the design and operation of these components is the same across all vehicle and component manufacturers.

Following these steps will have the vehicle and scope operating in no time.

1. Locate the Suction Control Valve (SCV) and pull back the outer sheathe about 50mm so that there is room for the current clamp.
2. Attach a 0-20A current clamp with the directional arrow pointing towards the SCV
3. Briefly start the engine and inspect your SCV amperage waveform, it should look similar to the sample below. If not, you may be connected to the negative side of the Suction Control Valve (SCV-)



Current clamp with polarity indicator

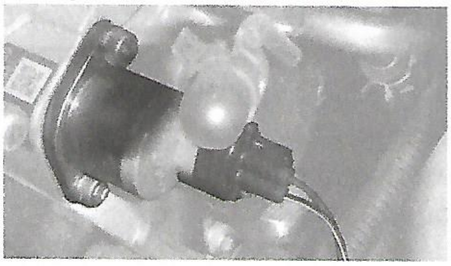


Example of current waveform

DIAGNOSIS continued...

4. Once you have located the SCV+ carefully backprobe the connector (same wire as the amp clamp is on)

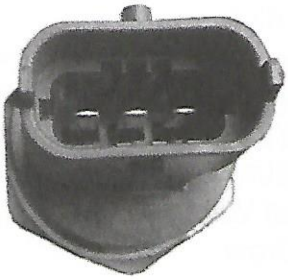
5. Locate the Fuel Rail Pressure Sensor and carefully backprobe the *middle* terminal (all FRPS have the signal in the middle with a power and ground either side)



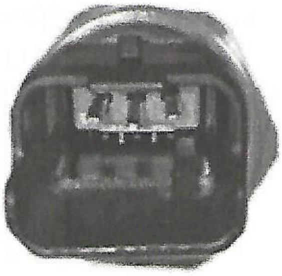
SCV & connector on a Mazda CX-7

Note:
Vehicles fitted with Denso Dual Fuel Rail Pressure Sensors can be backprobed into either centre pin!

6. Set your scope parameters:
   - SCV Backprobe - 20V DC
   - SCV Amp Clamp - 10A
   - FRPS Backprobe - 10V DC
   - Time - 200ms/div + zoom x64

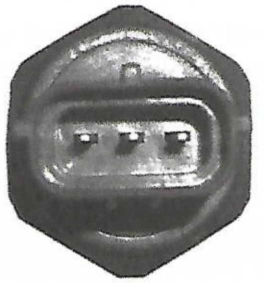


Bosch FRPS

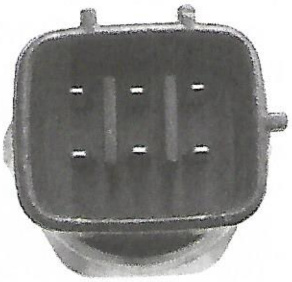


Delphi FRPS

Note:
These settings were used as a simple generic figure so that any vehicle can be compared on the settings and so that the example images in the Case Study can be used as a reference!



Denso FRPS



Denso dual FRPS

7. Start the engine and slide the zero scale for each trace so that the waveforms can be easily seen.

Check the waveforms for the following characteristics:

8. SCV 20V DC
   - Square waveform (duty cycle)
   - Straight vertical signals
   - Limited interference

9. SCV AMP
   - Sawtooth waveform
   - Limited interference
   - Defined switch points

10. FRPS 10V DC
    - Steady value
    - Slight (0.2V) increase with increased RPM

CASE STUDY

Information from the Customer

Vehicle description

The vehicle being tested was a 11/2005 Toyota Hilux KUN26R with a 3.0L 1KD engine and over 300,000km on the odometer.

Problem description

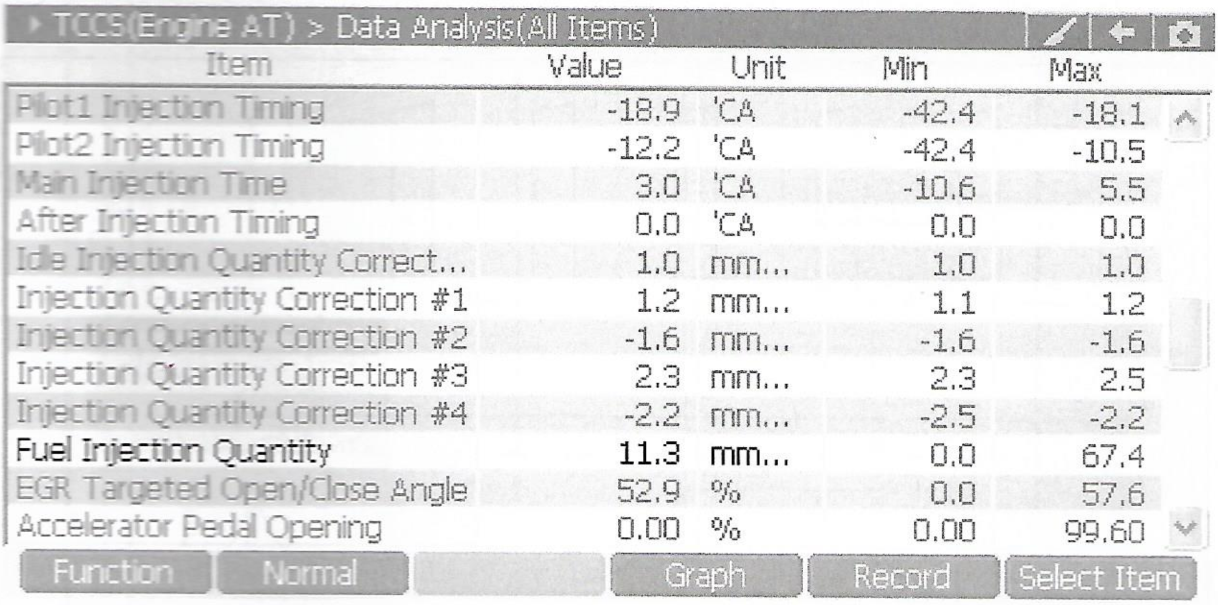
The vehicle would very intermittently run rough, stall and lack power. Fault occurs "a few times a week..." was the testimonial of the owner.

Problem conditions

Fault is completely intermittent but might be slightly more prominent when engine warm and high ambient temperature.

Basic Inspection

All of the basics were checked as per the Auto-Tech Diagnostic Flow Chart *(see: page 52)*. As the tests yielded no clues the engine and control system were thoroughly inspected using non-invasive tests such as Volumetric Efficiency, Cylinder Balance, Cylinder Quantity Corrections and Injection Quantity.



Item	Value	Unit	Min	Max
Pilot1 Injection Timing	-18.9	'CA	-42.4	-18.1
Pilot2 Injection Timing	-12.2	'CA	-42.4	-10.5
Main Injection Time	3.0	'CA	-10.6	5.5
After Injection Timing	0.0	'CA	0.0	0.0
Idle Injection Quantity Correct...	1.0	mm...	1.0	1.0
Injection Quantity Correction #1	1.2	mm...	1.1	1.2
Injection Quantity Correction #2	-1.6	mm...	-1.6	-1.6
Injection Quantity Correction #3	2.3	mm...	2.3	2.5
Injection Quantity Correction #4	-2.2	mm...	-2.5	-2.2
Fuel Injection Quantity	11.3	mm...	0.0	67.4
EGR Targeted Open/Close Angle	52.9	%	0.0	57.6
Accelerator Pedal Opening	0.00	%	0.00	99.60

Fuel Injection Quantity should be 5 to 12mm3/st @ idle

Results

While the fuel injection quantity is sitting close to the maximum threshold it indicated a rather even degradation of all four injectors that did not represent the fault indicated by the owner.

CASE STUDY continued...

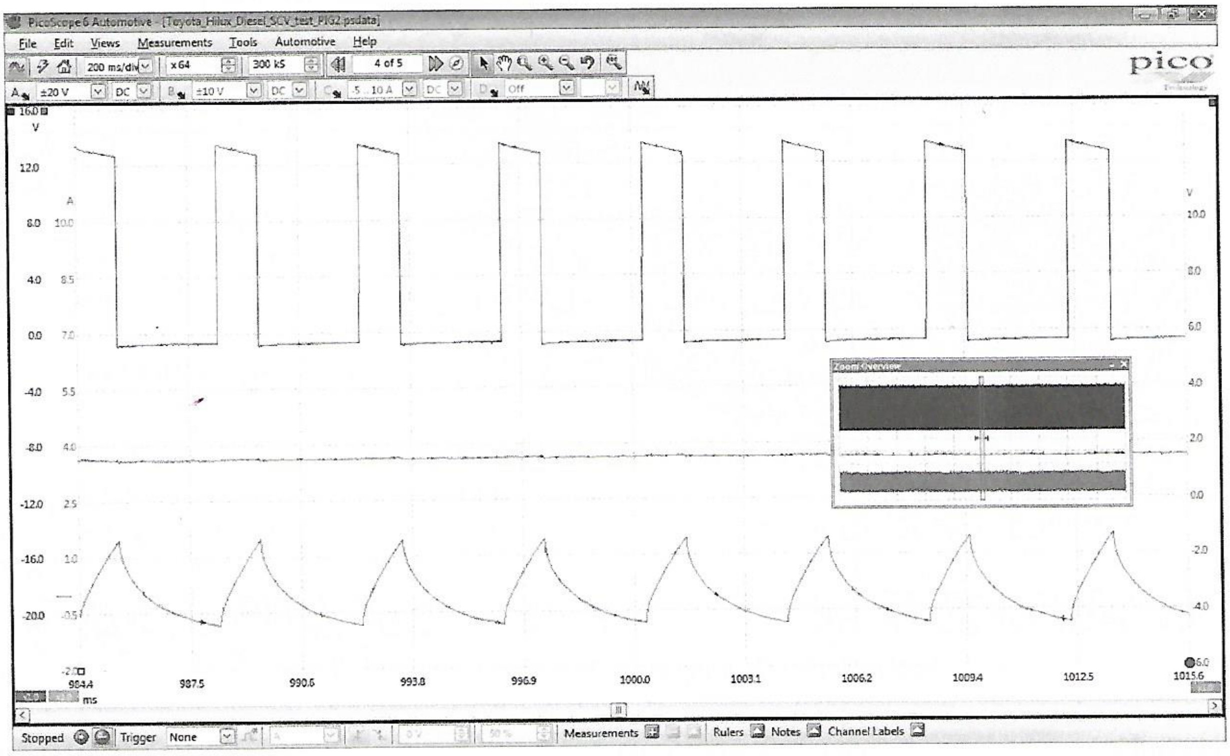
Detailed Inspection

With little else to work with it was decided to inspect the operation of the Suction Control Valve (SCV). The description of the vehicles fault fits with intermittent SCV failure and this can be supported by the condition of the fuel injectors and the vehicles mileage.

The resistance across the two terminals was 2.3 Ohms which is just within the parameter of 1.9 to 2.3 Ohms.

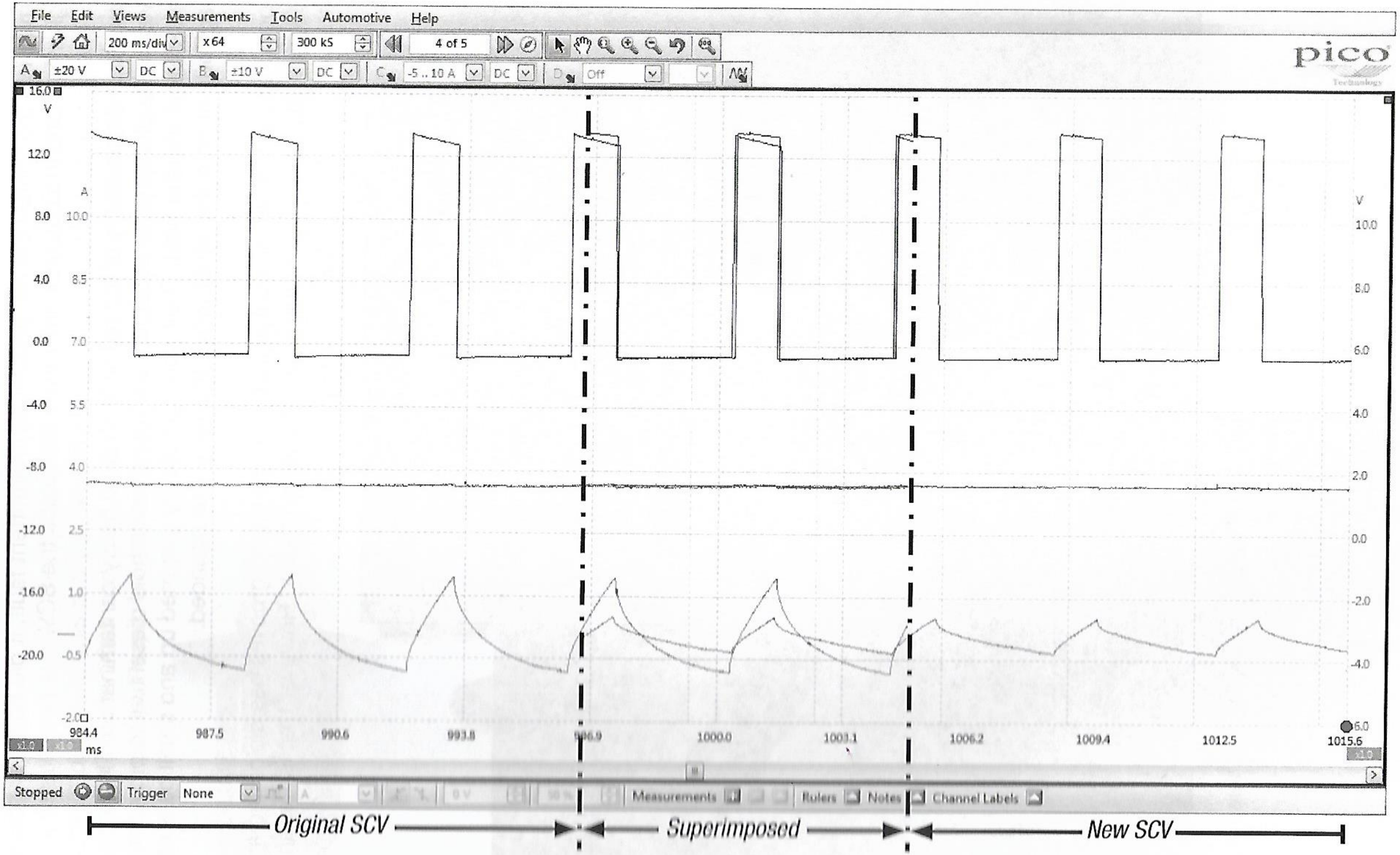
There is little to no data that can be extracted from a scan tool to give a conclusive diagnosis of the SCV. The most informative non-invasive test for checking the SCV is to monitor the pulse-width modulated command signal and the circuit current draw. It can also be beneficial to monitor the Fuel Rail Pressure Sensor (FRPS) because a sticking valve creates erratic changes to the rail pressure.

The scope was connected as per the Diagnosis topic on *pages 45-46* of this Technical Training Manual.


PicoScope 6 Automotive - [Toyota_Hilux_Diesel_SCV_test_PIG2.psdata]
File Edit Views Measurements Tools Automotive Help
200 ms/div
x64
300 kS
4 of 5
A ±20 V DC
B ±10 V DC
C 5 .. 10 A DC
D Off
pico
16.0
V
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
-16.0
-20.0
A
10.0
8.5
7.0
5.5
4.0
2.5
1.0
-0.5
-2.0
V
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
Zoom Overview
984.4
987.5
990.6
993.8
996.9
1000.0
1003.1
1006.2
1009.4
1012.5
1015.6
ms
Stopped
Trigger None
Measurements
Rulers
Notes
Channel Labels

CASE STUDY continued...

Superimposed waveforms for before and after SCV replacement



200 ms/div

x64

300 kS

4 of 5

A ±20 V DC

B ±10 V DC

C -5 .. 10 A DC

D Off

Stopped

Trigger None

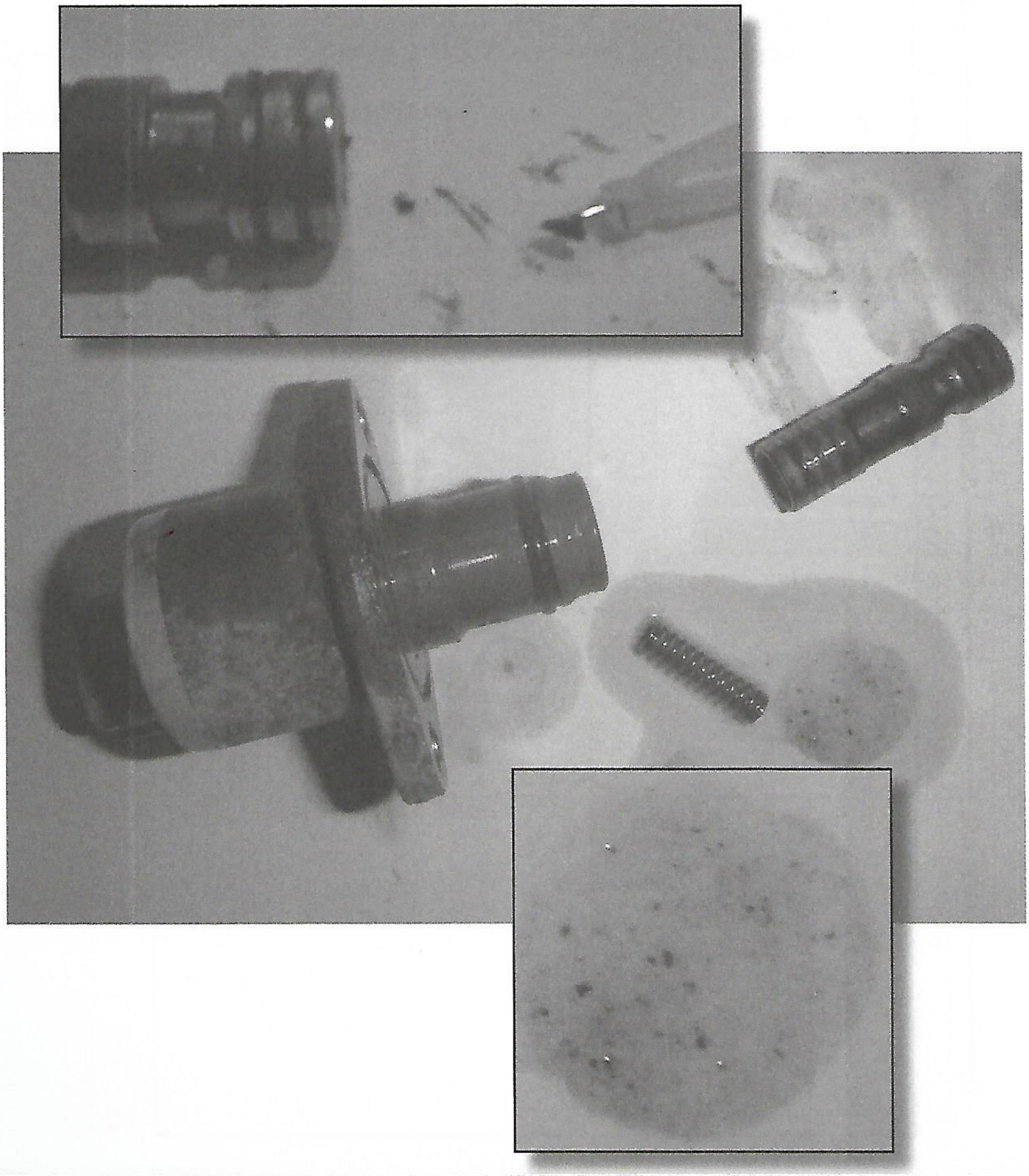
File
Edit
Views
Measurements
Tools
Automotive
Help
pico Technology
16.0
V
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
-16.0
-20.0
A
10.0
8.5
7.0
5.5
4.0
2.5
1.0
-0.5
-2.0
V
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
984.4
987.5
990.6
993.8
996.9
1000.0
1003.1
1006.2
1009.4
1012.5
1015.6
ms
x1.0
Measurements
Rulers
Notes
Channel Labels
Original SCV
Superimposed
New SCV

CASE STUDY continued...

Unfortunately the vehicle did not present its intermittent fault, it did however provide enough information to convince the owner to replace the SCV.

Removal and disassembly of the old SCV showed heavy contamination. The grooves in the piston/valve assembly are supposed to hold diesel fuel to provide lubrication and transfer heat. They were completely gummed up and small balls of gum spilled out onto the bench when the valve was upended.

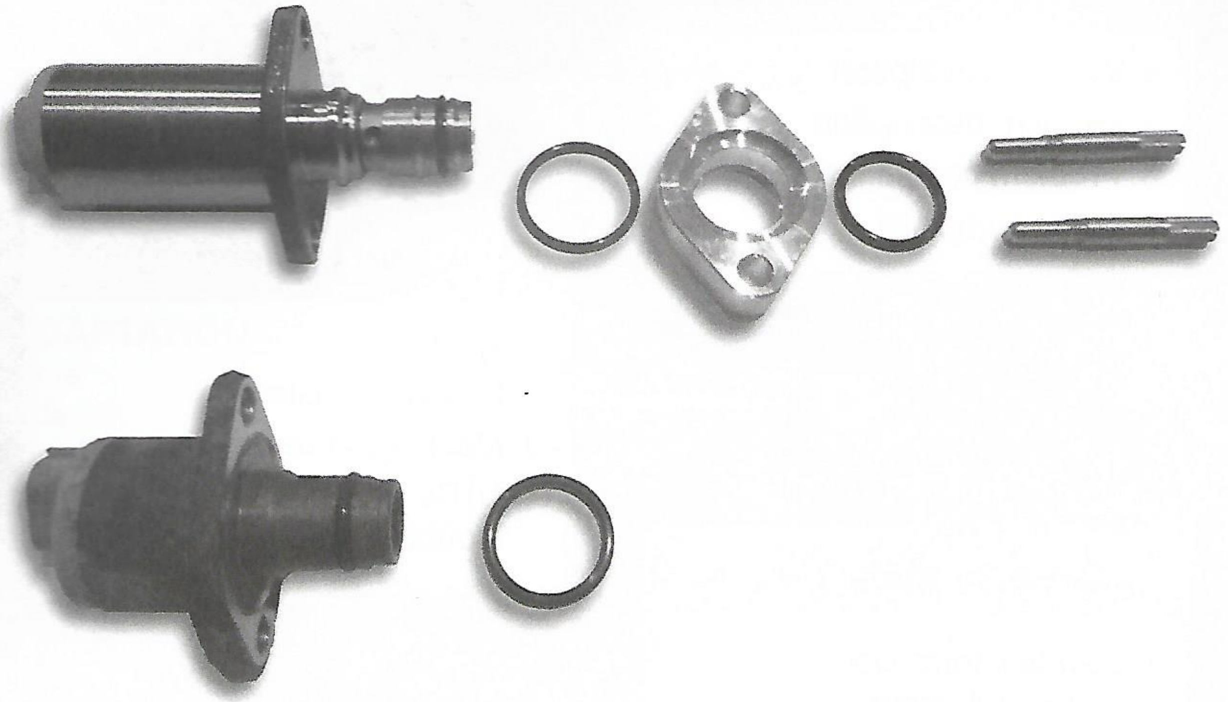
One possibility is that as the contamination in the piston grooves has dislodged and rolled into balls, it has temporarily cause the valve to stick. However that is just an hypothesis!



CASE STUDY continued...

Repair

This vehicle was subject to a SCV retrofit from the Compact SCV to the Conventional SCV. This is a very common retrofit required across many Denso CRD systems between 2005 and 2010. Your Denso part supplier will ask for the serial number the High Pressure Fuel Pump and will supply the appropriate SCV.



The replacement SCV (upper) includes adapter plate and 'O'-rings, installation alignment pins and new longer bolts (not pictured)

Relearn

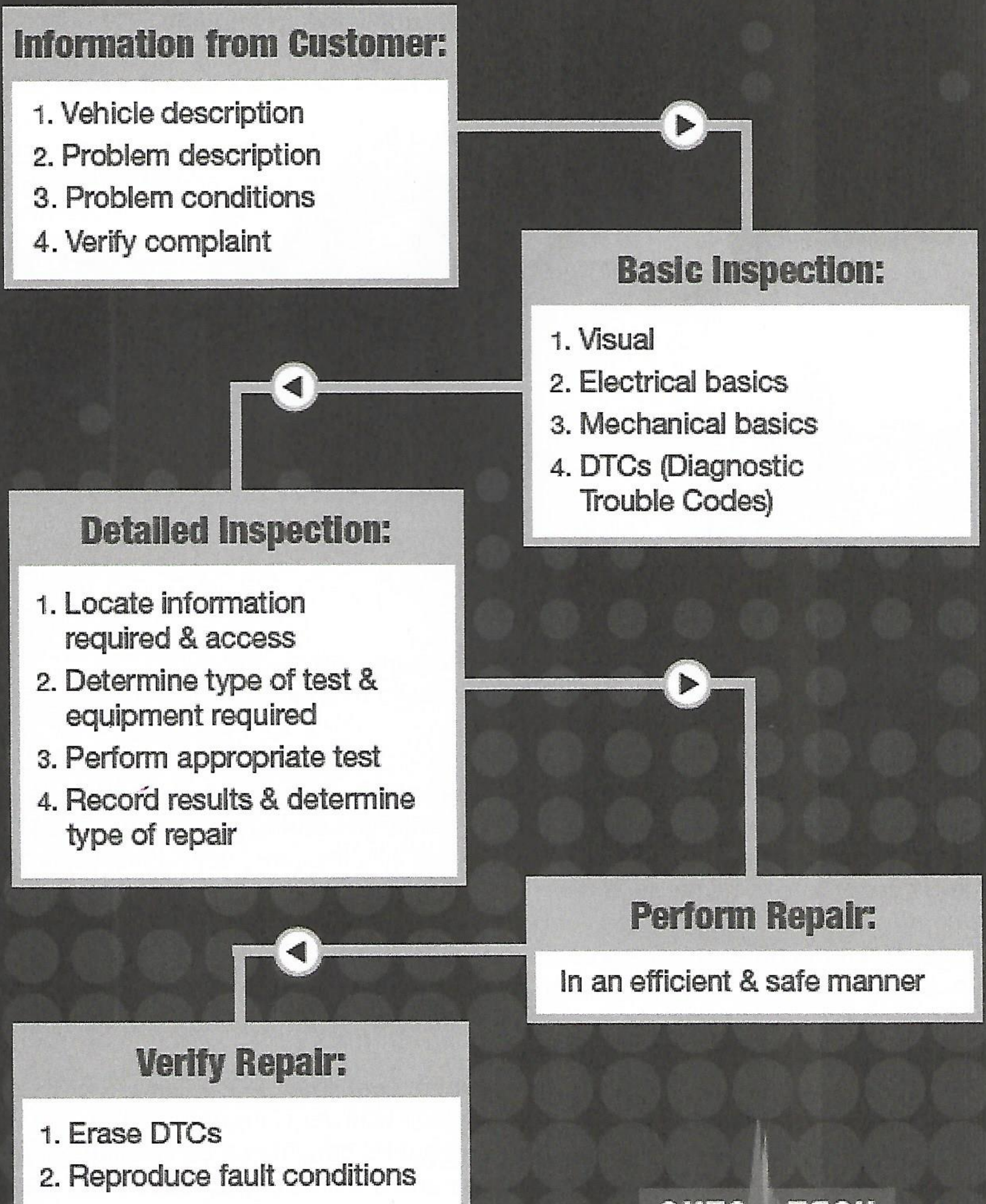
After a new SCV has been fitted, the ECM needs to learn its operational attributes. Failure to do the relearn can cause all of the symptoms attributed to a faulty SCV. The SCV Relearn is also known as Supply Pump Initialisation, Fuel Pump Relearn or Pump Learn Clear to name but a few.

The relearn procedure can be carried out by following the prompts in the Special Functions menu of a compatible scan tool.

Verification

First point of verification is the reduced current draw evident in the 'New SCV' section of the waveforms on *page 49*. As the fault was very intermittent and unpredictable even an extended road test can not be considered as verification. It has now been two months between the repair and the time of publication and the fault has not reoccurred!

Diagnostic Process – Logical Flow



Information from Customer:

1. Vehicle description
2. Problem description
3. Problem conditions
4. Verify complaint

Basic Inspection:

1. Visual
2. Electrical basics
3. Mechanical basics
4. DTCs (Diagnostic Trouble Codes)

Detailed Inspection:

1. Locate information required & access
2. Determine type of test & equipment required
3. Perform appropriate test
4. Record results & determine type of repair

Perform Repair:

In an efficient & safe manner

Verify Repair:

1. Erase DTCs
2. Reproduce fault conditions
3. Re-check for DTCs
4. Confirm vehicle correct operation

Section iv

Fuel Adaptation Tables
What do they *really* mean?

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FUTURE DEVELOPMENTS **74**

INTRODUCTION

The fuel adaptation tables are used to alter the fuel injection quantities in order to achieve smoother engine operation. The scope and limitations of these adaptations will be discussed on the following pages.

While most manufacturers provide these values in the Scan Tool Data, there are a few that don't. The other impacting factor is whether the maker/programmer of your aftermarket scan tool has programmed all of the parameters for any specific vehicle. The terms (names) used by manufacturers for this parameter varies, here are a few that are known:

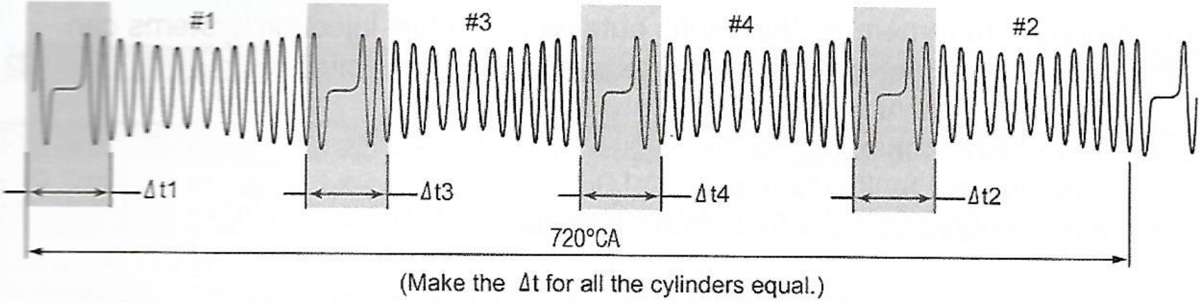
- Cylinder Balancing Offset (Land Rover with Siemens VDO)
- Cylinder Contribution/Balance (Ford with Siemens VDO)
- Fuel Balancing Quantity (Ford with Siemens VDO)
- Fuel Control for Cylinder Balance (Denso)
- Fuel Injection Quantity Offset (Nissan with Denso)
- Idle Stabilisation (VW AG with Bosch)
- Injection Amount Correction (Citroen, Holden, Mazda with Denso)
- Injection Feedback Value (Toyota with Denso)
- Injection Quantity Correction (Toyota, Mitsubishi, Subaru with Denso)
- Injection Quantity Deviation (VW AG with Bosch)
- Injection Quantity Learning (Nissan with Denso)
- Microinjection Quantity Learning (Toyota, Mazda, Subaru with Denso)
- Perform Pilot Correction Learn (Ford with Denso)
- Pilot Quantity Learning (Toyota with Denso)
- Small Injection Quantity Learning (Mitsubishi with Denso)

FUNCTION

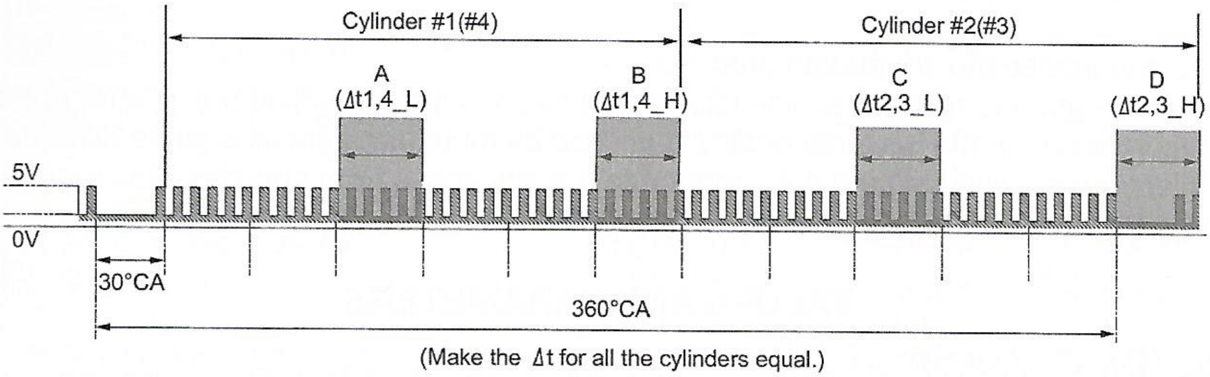
All of these different terms relate to the same single principle, to smooth out idle instability, noise and emissions! What's more they all identify the idle instability with the same sensor...

FUNCTION continued...

The Crankshaft Position Sensor (or whatever you might prefer to call it) is monitored for deviations!
The ECM is programmed to compare the time taken for the crankshaft to rotate a specific number of degrees after combustion, the same sample window is monitored for each cylinder.



Example of sample range (in grey) for engine using an inductive type Crankshaft Position Sensor



Example of sample range (in grey) for engine using a hall effect type Crankshaft Position Sensor

In order to measure the rotational time it is essential to have the engine operating in a controlled environment where engine load variations will not affect the sample. For this reason all but one of the 21 system combinations mentioned on the previous page carry out the test with the engine at IDLE!

The Toyota Prado KDJ150R with a 1KD engine is the only vehicle found that takes its sample by triggering a single microinjection while the vehicle is in fuel cut deceleration. Allowing the micro injections to be checked at much higher rail pressures (approximately 100 MPa). This feature is NOT available on the previous KDJ120R or any Hilux and Hiace models fitted with the KD series engines.

Another slight variation of the aforementioned adaptation processes is the Micro-injection Quantity Learning Control used by Denso in many of their systems, from 2007 onwards. Used under many names (most commonly Small Injection Quantity Learning in Mitsubishi Pajero) this feature replaces the standard pilot injection with five consecutive micro injections and monitors the crankshaft acceleration at idle.

FUNCTION continued...

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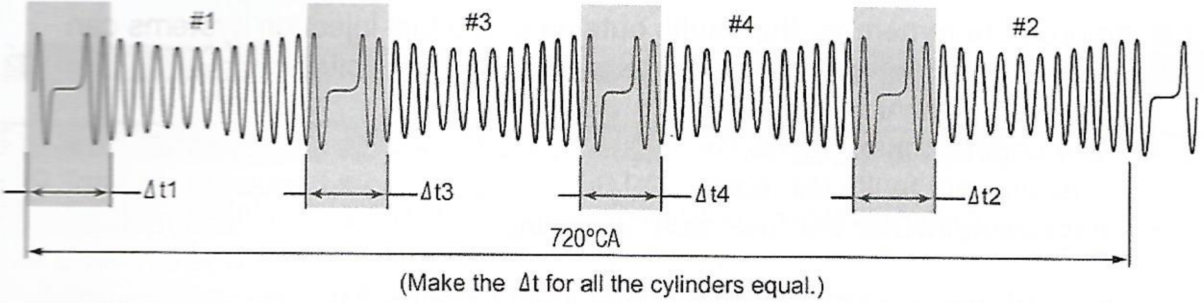
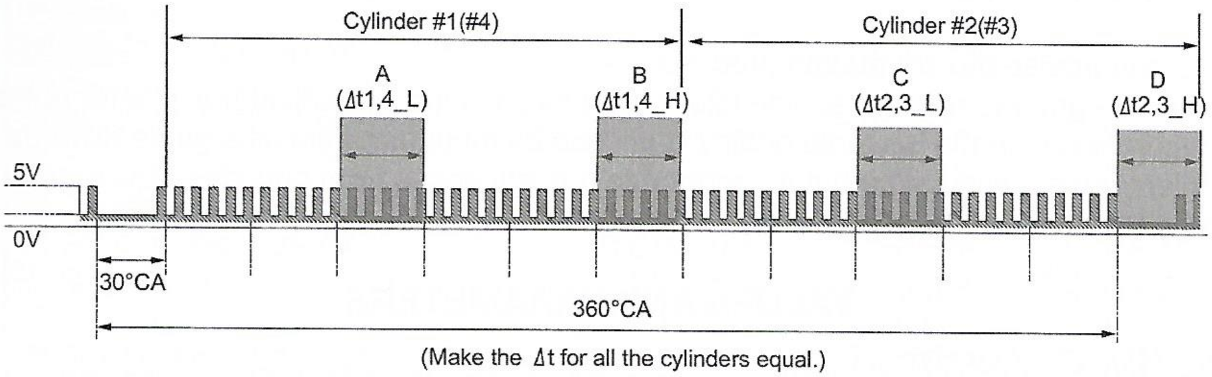


Example of sample range (in grey) for engine using an inductive type Crankshaft Position Sensor



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ADAPTATION

All of these adaptation processors are used to adjust the injection pulse width (on-time) to ensure that all cylinders are creating the same amount of power output (torque). What is not often understood is that the fuel adaptation ONLY AFFECTS IDLE! They have no affect on fuel injection quantities as soon as the engine is off idle.

It is important to remember that faults outside of the fuel injection systems can cause variations in the fuel adaptation tables. The faults include:

- Engine mechanical faults
- Any engine control faults
- Fuel delivery faults (air leaks)
- Excessive/Insufficient fuel return pressure

Another shortcoming of this system is that it only monitors the injectors operation at idle rail pressure (typically 30-40MPa). This means that the injector faults that are accentuated by pressure are either missed or inadequately adapted.

To summarise the adaptation process;
It is designed to monitor engine idle for inconsistencies and adjust the injector pulse width to obtain the best idle quality. It is used by manufacturers as a guide towards injector wear and failure but it cannot rule out influences from outside of the control system. Lastly, adaptation has zero effect above idle!

VALUES AND PARAMETERS

There are a few ways in which manufacturers display the adaptation values and their acceptable deviations. Adaptation values can be in reference to:

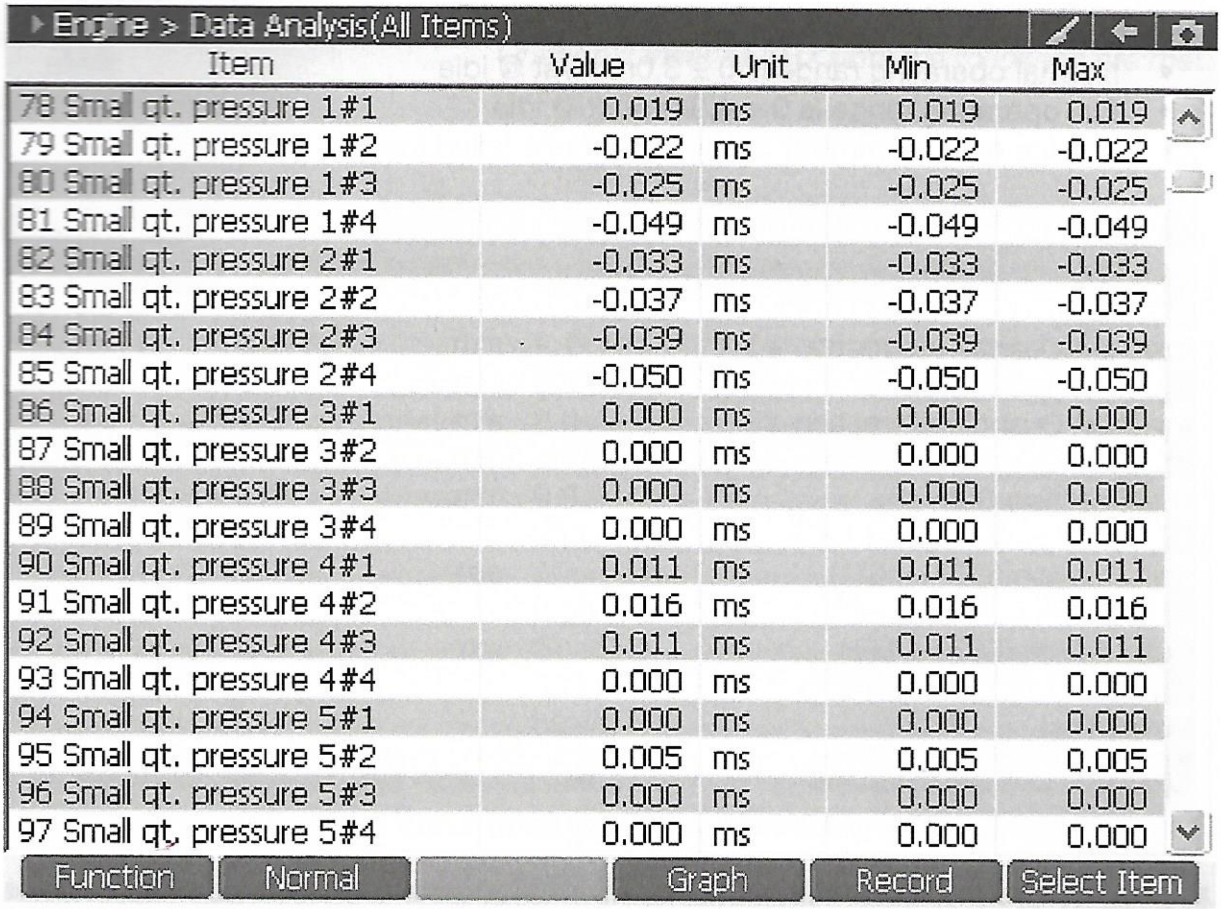
- Time
- Quantity
- Weight
- Arbitrary (no direct relationship between value and action)

Note: *REMEMBER, that regardless of the unit value, ALL systems monitor the crankshaft to identify irregularities and adjust the injector pulse width to make variations!*

VALUES AND PARAMETERS continued...

Time

Using time as the adaptation value is the most relevant to the actual process being conducted by the ECM, because any adjustments are made by increasing or decreasing the pulse width (on-time). Surprisingly this seems to be one of the least used values. When time is used as the adaptation value, the value is displayed in either milliseconds (ms) or microseconds (µs).



Item	Value	Unit	Min	Max
78 Small qt. pressure 1#1	0.019	ms	0.019	0.019
79 Small qt. pressure 1#2	-0.022	ms	-0.022	-0.022
80 Small qt. pressure 1#3	-0.025	ms	-0.025	-0.025
81 Small qt. pressure 1#4	-0.049	ms	-0.049	-0.049
82 Small qt. pressure 2#1	-0.033	ms	-0.033	-0.033
83 Small qt. pressure 2#2	-0.037	ms	-0.037	-0.037
84 Small qt. pressure 2#3	-0.039	ms	-0.039	-0.039
85 Small qt. pressure 2#4	-0.050	ms	-0.050	-0.050
86 Small qt. pressure 3#1	0.000	ms	0.000	0.000
87 Small qt. pressure 3#2	0.000	ms	0.000	0.000
88 Small qt. pressure 3#3	0.000	ms	0.000	0.000
89 Small qt. pressure 3#4	0.000	ms	0.000	0.000
90 Small qt. pressure 4#1	0.011	ms	0.011	0.011
91 Small qt. pressure 4#2	0.016	ms	0.016	0.016
92 Small qt. pressure 4#3	0.011	ms	0.011	0.011
93 Small qt. pressure 4#4	0.000	ms	0.000	0.000
94 Small qt. pressure 5#1	0.000	ms	0.000	0.000
95 Small qt. pressure 5#2	0.005	ms	0.005	0.005
96 Small qt. pressure 5#3	0.000	ms	0.000	0.000
97 Small qt. pressure 5#4	0.000	ms	0.000	0.000

Small Quantity Injections adaptation values from a 2010 Mitsubishi Pajero 4M41 in milliseconds to 3 decimal places (0.001ms = 1µs).

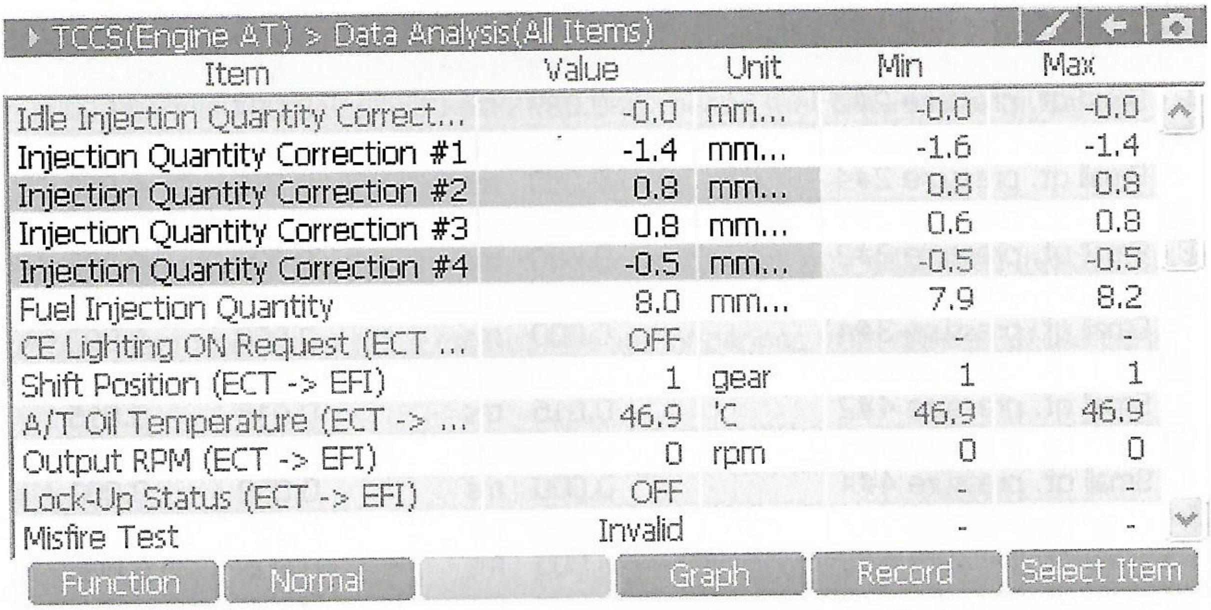
Note: *Mitsubishi do not use the small quantity injection adaption for diagnostic purposes nor do they provide a normal operating range!*

VALUES AND PARAMETERS continued...

Quantity
The adaptation value can also be offered as an inferred measurement of the quantity of the fuel sample delivered at each power stroke. When quantity is used as the adaptation value, the value is displayed in cubic millimetres per stroke (mm3/st). This is the preferred value used by most Denso systems.

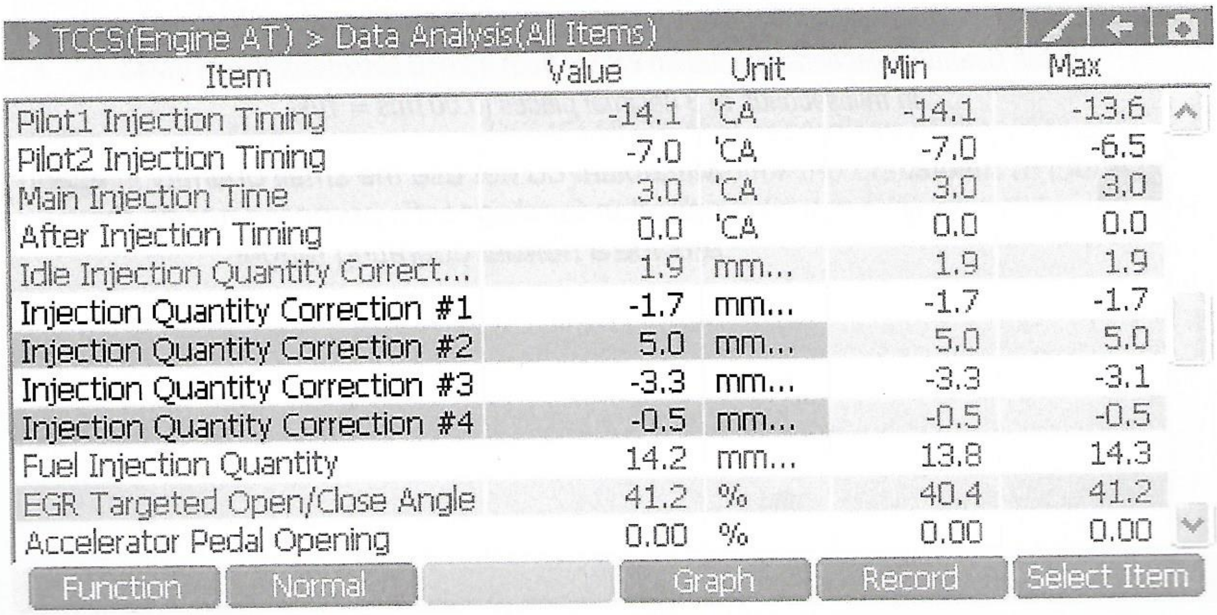
Toyota 1KD - Parameters
Toyota states that:

- Normal operating range is 0 ± 3.0mm^3/st @ idle
- Full operating range is 0 ± 4.9mm^3/st @ idle
- A value of ± 5.0mm^3/st @ idle indicates a failed injector



Item	Value	Unit	Min	Max
Idle Injection Quantity Correct...	-0.0	mm...	-0.0	-0.0
Injection Quantity Correction #1	-1.4	mm...	-1.6	-1.4
Injection Quantity Correction #2	0.8	mm...	0.8	0.8
Injection Quantity Correction #3	0.8	mm...	0.6	0.8
Injection Quantity Correction #4	-0.5	mm...	-0.5	-0.5
Fuel Injection Quantity	8.0	mm...	7.9	8.2
CE Lighting ON Request (ECT ...	OFF		-	-
Shift Position (ECT -> EFI)	1	gear	1	1
A/T Oil Temperature (ECT -> ...	46.9	'C	46.9	46.9
Output RPM (ECT -> EFI)	0	rpm	0	0
Lock-Up Status (ECT -> EFI)	OFF		-	-
Misfire Test	Invalid		-	-

Example of a 2009 Hilux operating within normal specifications



Item	Value	Unit	Min	Max
Pilot1 Injection Timing	-14.1	'CA	-14.1	-13.6
Pilot2 Injection Timing	-7.0	'CA	-7.0	-6.5
Main Injection Time	3.0	'CA	3.0	3.0
After Injection Timing	0.0	'CA	0.0	0.0
Idle Injection Quantity Correct...	1.9	mm...	1.9	1.9
Injection Quantity Correction #1	-1.7	mm...	-1.7	-1.7
Injection Quantity Correction #2	5.0	mm...	5.0	5.0
Injection Quantity Correction #3	-3.3	mm...	-3.3	-3.1
Injection Quantity Correction #4	-0.5	mm...	-0.5	-0.5
Fuel Injection Quantity	14.2	mm...	13.8	14.3
EGR Targeted Open/Close Angle	41.2	%	40.4	41.2
Accelerator Pedal Opening	0.00	%	0.00	0.00

Example of a 2005 Hilux with one failed injector and another outside of normal range

VALUES AND PARAMETERS continued...

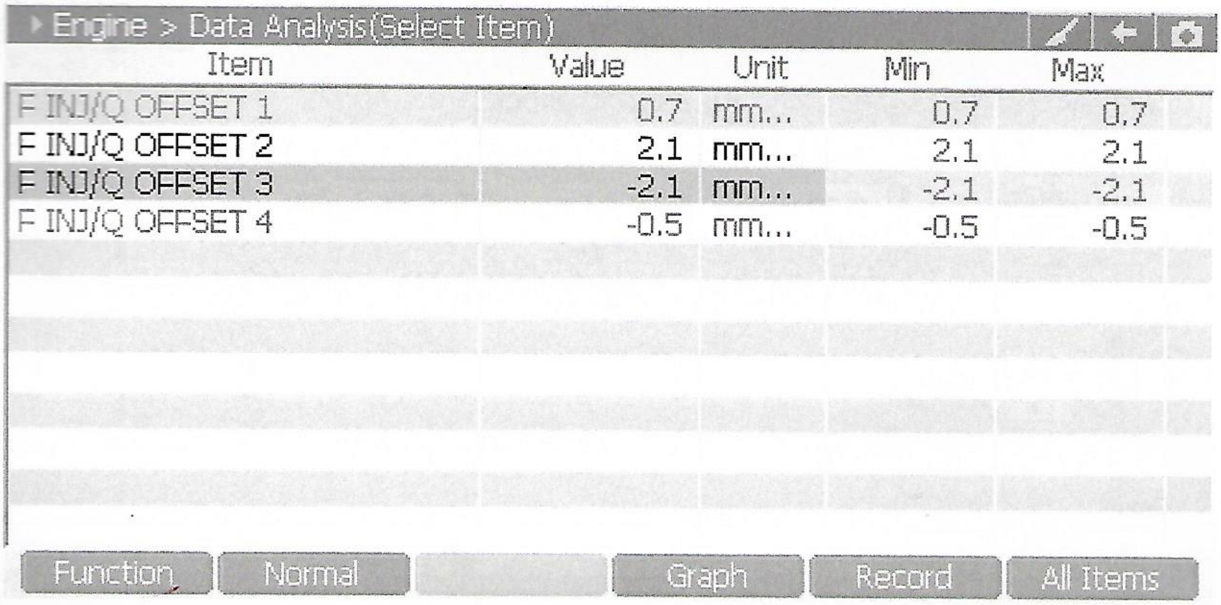
Nissan YD25 - Parameters

Nissan states that:

- Normal operating range is 0 ± 2.1mm³/st @ idle
- If an injector reads 2.1mm³/st it should be replaced
- If the vehicle has poor idle, noise or performance issues and one injector is found to be in the opposite spectrum, the odd injector should be replaced

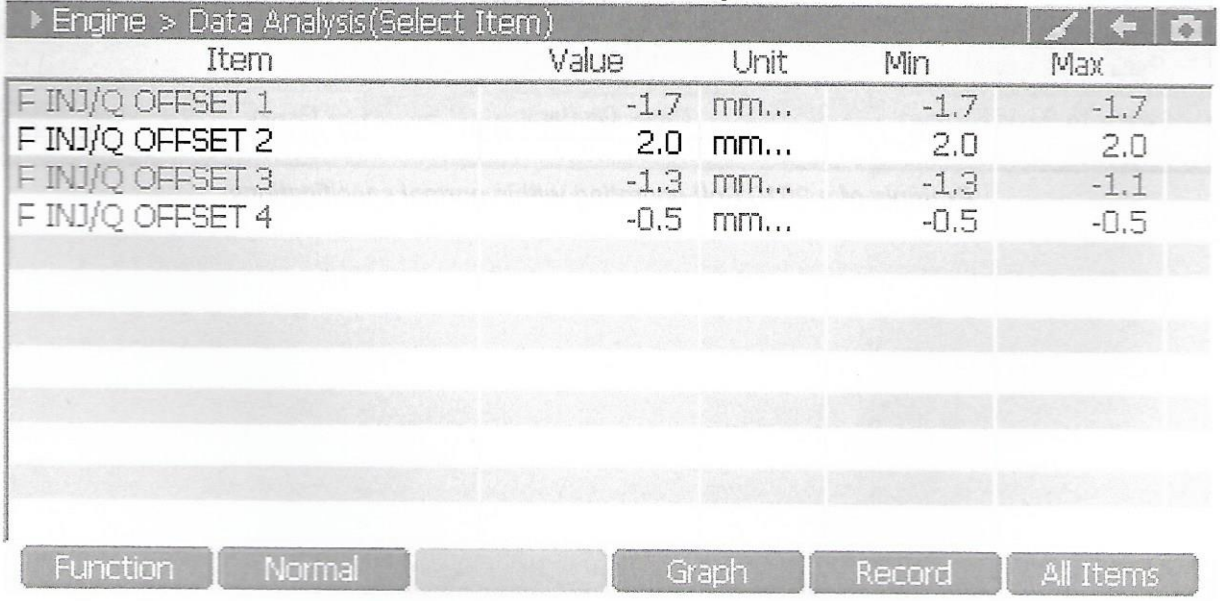
Caution: *Nissan YD25 engines will display a Fuel Injection Quantity Offset of '0.0' until the following are met:*

- No DTC's set
- Coolant temp above 60°C
- Engine idling
- Shift lever in Neutral


Engine > Data Analysis(Select Item)
Function
Normal
Graph
Record
All Items

Item	Value	Unit	Min	Max
F INJ/Q OFFSET 1	0.7	mm...	0.7	0.7
F INJ/Q OFFSET 2	2.1	mm...	2.1	2.1
F INJ/Q OFFSET 3	-2.1	mm...	-2.1	-2.1
F INJ/Q OFFSET 4	-0.5	mm...	-0.5	-0.5

Example of a 2009 Navara with two injectors at threshold


Engine > Data Analysis(Select Item)
Function
Normal
Graph
Record
All Items

Item	Value	Unit	Min	Max
F INJ/Q OFFSET 1	-1.7	mm...	-1.7	-1.7
F INJ/Q OFFSET 2	2.0	mm...	2.0	2.0
F INJ/Q OFFSET 3	-1.3	mm...	-1.3	-1.1
F INJ/Q OFFSET 4	-0.5	mm...	-0.5	-0.5

Example of a 2009 Navara with one injector on the opposite spectrum

VALUES AND PARAMETERS continued...

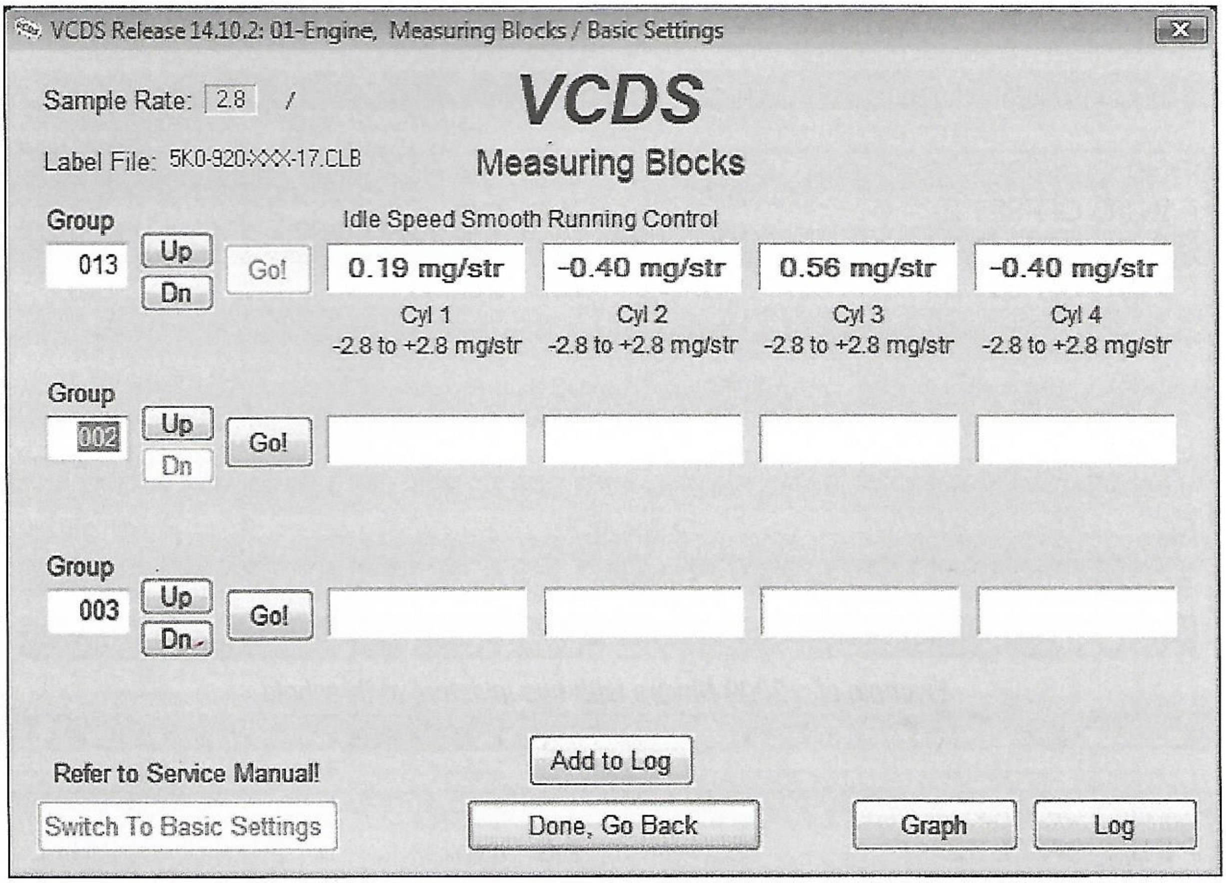
Weight

Weight is another unit of measurement used to display the fuel adaptation values. There are two main ways the value is displayed, either milligrams per stroke (mg/st) or grams per kilowatt hour (g/kWh).

Note: *Some french derived vehicles (including some Nissan's) use mg/Cp, Coup (Cp) translates to stroke!*

VW 1.6L TDI - Parameters

- Normal operating range is 0 ± 2.8mg/st @ idle



VCDS Release 14.10.2: 01-Engine, Measuring Blocks / Basic Settings

Sample Rate: 2.8

Label File: 5K0-920-XXX-17.CLB

VCDS

Measuring Blocks

Group 013 – Idle Speed Smooth Running Control

Cyl 1	Cyl 2	Cyl 3	Cyl 4
0.19 mg/str	-0.40 mg/str	0.56 mg/str	-0.40 mg/str
-2.8 to +2.8 mg/str	-2.8 to +2.8 mg/str	-2.8 to +2.8 mg/str	-2.8 to +2.8 mg/str

Group 002

Group 003

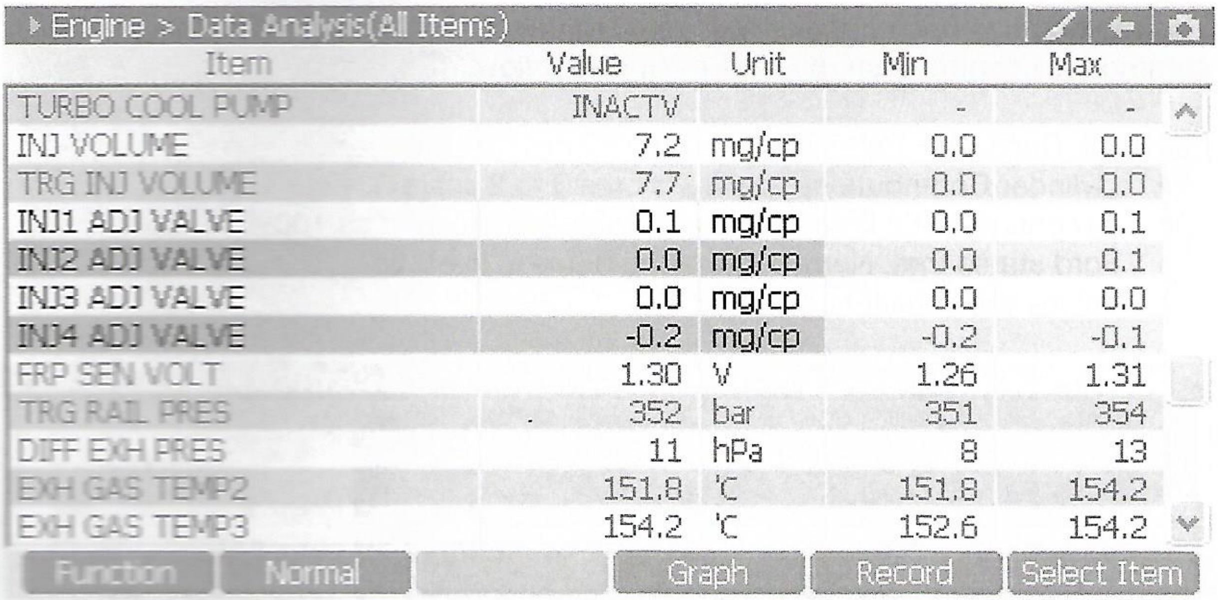
Refer to Service Manual!

Example of a 2010 Golf operating within normal specifications

VALUES AND PARAMETERS continued...

Nissan 2.0L M9R - Parameters

- Normal operating range is not provided by the manufacturer
- DTC's: P0263 (CYL#1), P0266 (CYL#2), P0269 (CYL#3) & P0272 (CYL#4) will be set by the ECM if the range is exceeded



Item	Value	Unit	Min	Max
TURBO COOL PUMP	INACTV		-	-
INJ VOLUME	7.2	mg/cp	0.0	0.0
TRG INJ VOLUME	7.7	mg/cp	0.0	0.0
INJ1 ADJ VALVE	0.1	mg/cp	0.0	0.1
INJ2 ADJ VALVE	0.0	mg/cp	0.0	0.1
INJ3 ADJ VALVE	0.0	mg/cp	0.0	0.0
INJ4 ADJ VALVE	-0.2	mg/cp	-0.2	-0.1
FRP SEN VOLT	1.30	V	1.26	1.31
TRG RAIL PRES	352	bar	351	354
DIFF EXH PRES	11	hPa	8	13
EXH GAS TEMP2	151.8	℃	151.8	154.2
EXH GAS TEMP3	154.2	℃	152.6	154.2

Example of a 2010 X-Trail operating within normal specifications

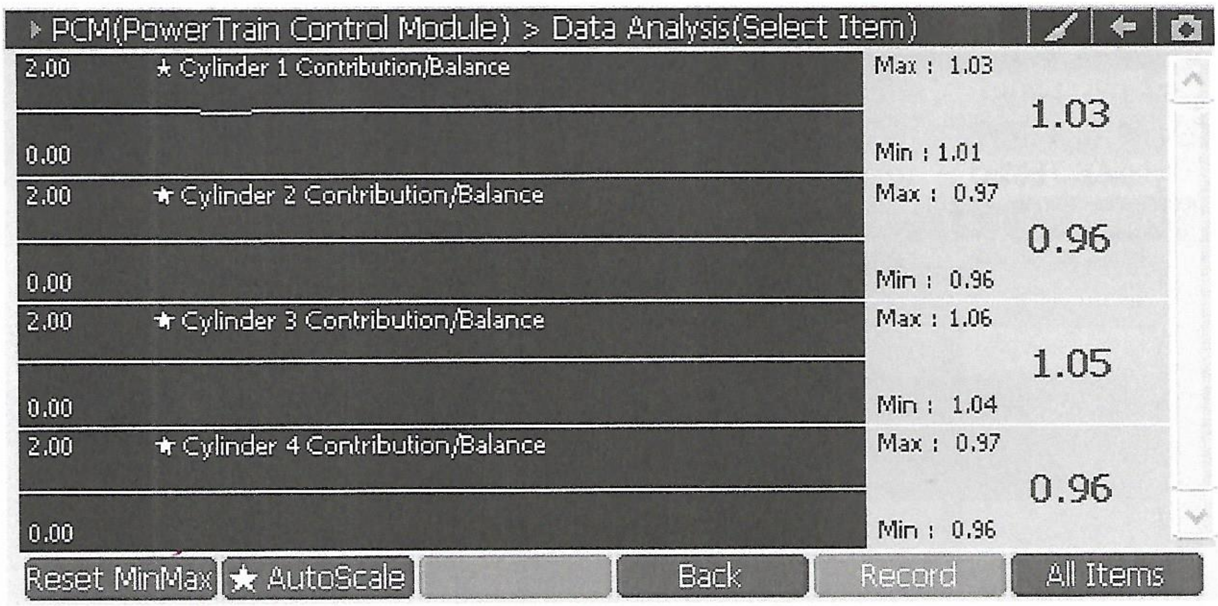
VALUES AND PARAMETERS continued...

Arbitrary
Another method used to display the adaptation values is to pick a value and then adjusting the value either side of the optimal value. The value has no direct relevance with the injection quantity.

This method has been popular with vehicles using the Continental/Siemems/VDO common rail control systems. Two examples follow:

Ford 2.0L Duratorq - Parameters

- Cylinder Contribution/Balance is on a 0 to 2 scale
- 1 represents the baseline (it might help to think of it as 100%)
- Ford states that: Normal operating range is 0 ± 0.25
- Values will default to 1 above idle

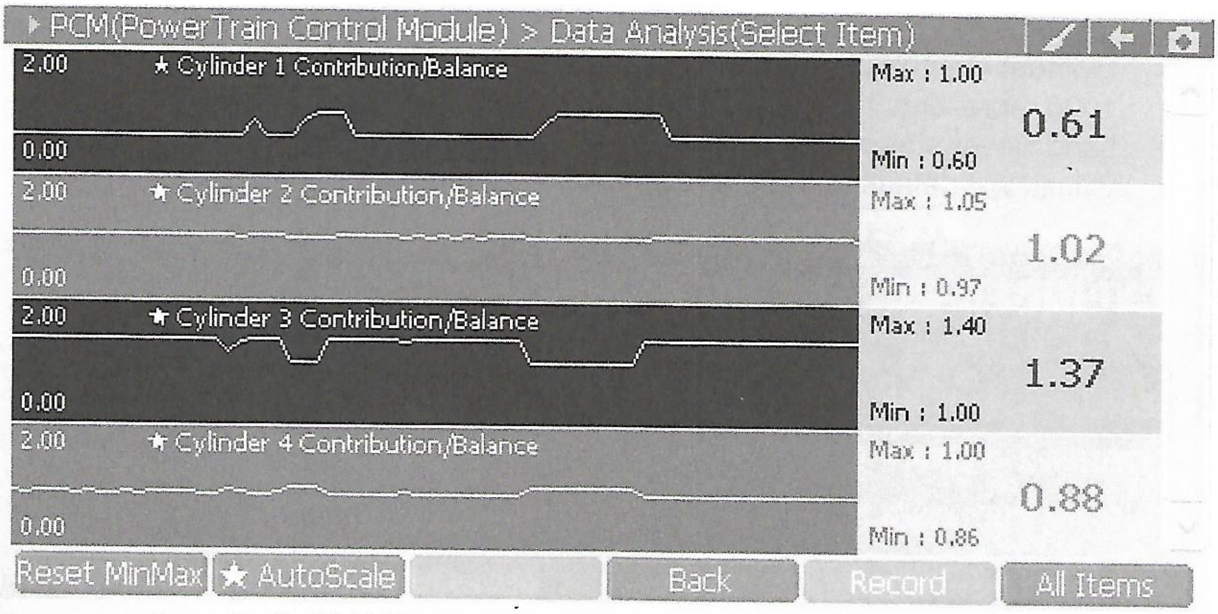


PCM(PowerTrain Control Module) > Data Analysis(Select Item)

Scale	Item	Max	Value	Min
2.00 / 0.00	★ Cylinder 1 Contribution/Balance	1.03	1.03	1.01
2.00 / 0.00	★ Cylinder 2 Contribution/Balance	0.97	0.96	0.96
2.00 / 0.00	★ Cylinder 3 Contribution/Balance	1.06	1.05	1.04
2.00 / 0.00	★ Cylinder 4 Contribution/Balance	0.97	0.96	0.96

Example of a 2008 Focus operating within normal specifications

VALUES AND PARAMETERS continued...



PCM(PowerTrain Control Module) > Data Analysis(Select Item)

★ Cylinder 1 Contribution/Balance Max : 1.00 0.61 Min : 0.60

★ Cylinder 2 Contribution/Balance Max : 1.05 1.02 Min : 0.97

★ Cylinder 3 Contribution/Balance Max : 1.40 1.37 Min : 1.00

★ Cylinder 4 Contribution/Balance Max : 1.00 0.88 Min : 0.86

Example of a 2008 Focus operating within two cylinders out of specifications

Note: *It is most likely that the cylinders with the high offsets are the cause of the fault and the low values are trying to compensate!*

HOWEVER, this is not always the case...

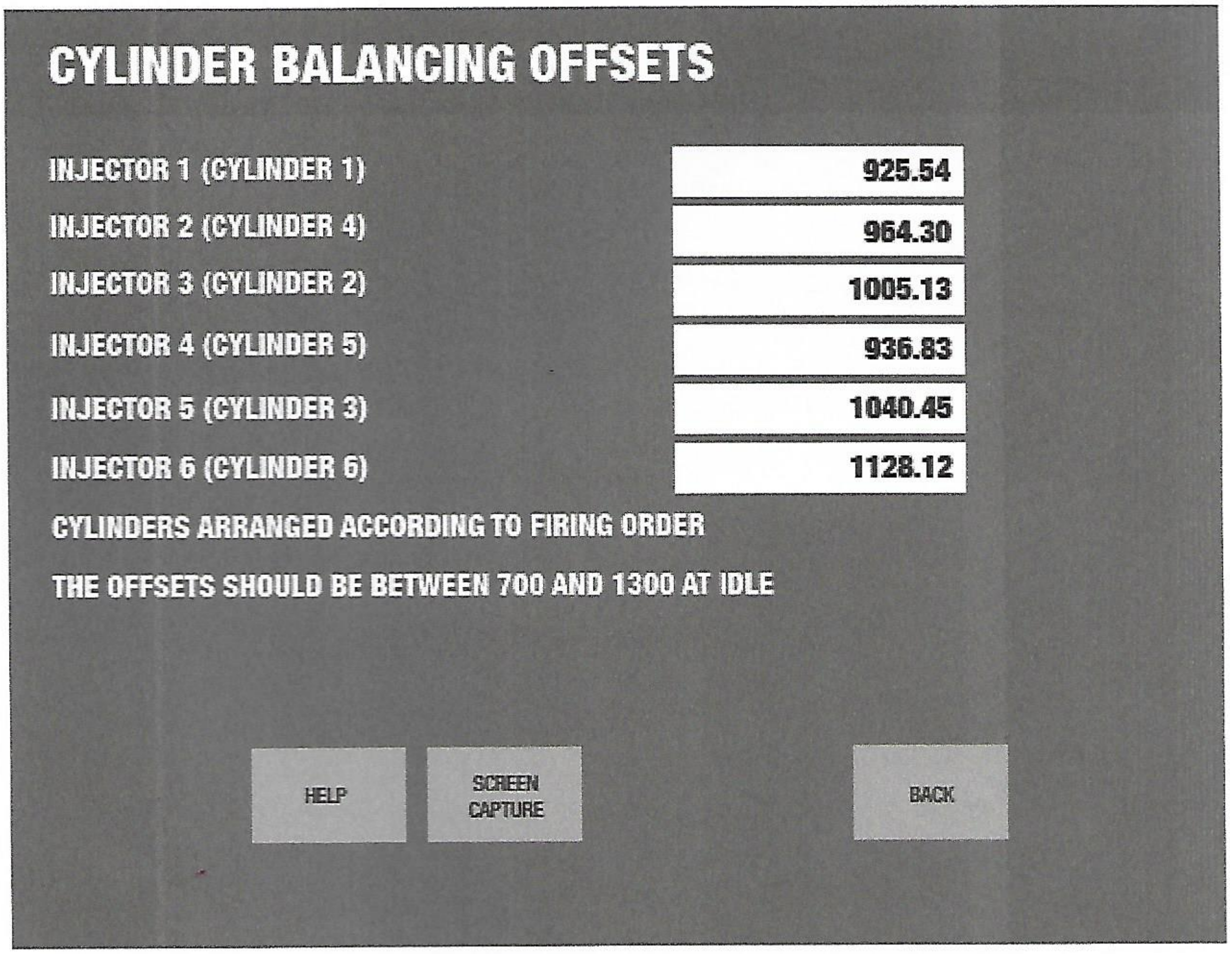
ALWAYS carry out full diagnosis before replacing parts!

Note: *The cause and diagnosis of this particular vehicle is provided in the Diagnosis topic (pages 66-72) of this chapter!*

VALUES AND PARAMETERS continued...

Land Rover TDV6 - Parameters

- Cylinder Contribution/Balance is on a 0 to 2000 scale
- 1000 represents the baseline (it might help to think of it as 100%)
- Land Rover states that: Normal operating range is 700 to 1300
- Values will default to 1000 above idle



CYLINDER BALANCING OFFSETS

INJECTOR 1 (CYLINDER 1)	925.54
INJECTOR 2 (CYLINDER 4)	964.30
INJECTOR 3 (CYLINDER 2)	1005.13
INJECTOR 4 (CYLINDER 5)	936.83
INJECTOR 5 (CYLINDER 3)	1040.45
INJECTOR 6 (CYLINDER 6)	1128.12

CYLINDERS ARRANGED ACCORDING TO FIRING ORDER

THE OFFSETS SHOULD BE BETWEEN 700 AND 1300 AT IDLE

Example of a Discovery 3 operating within normal specifications

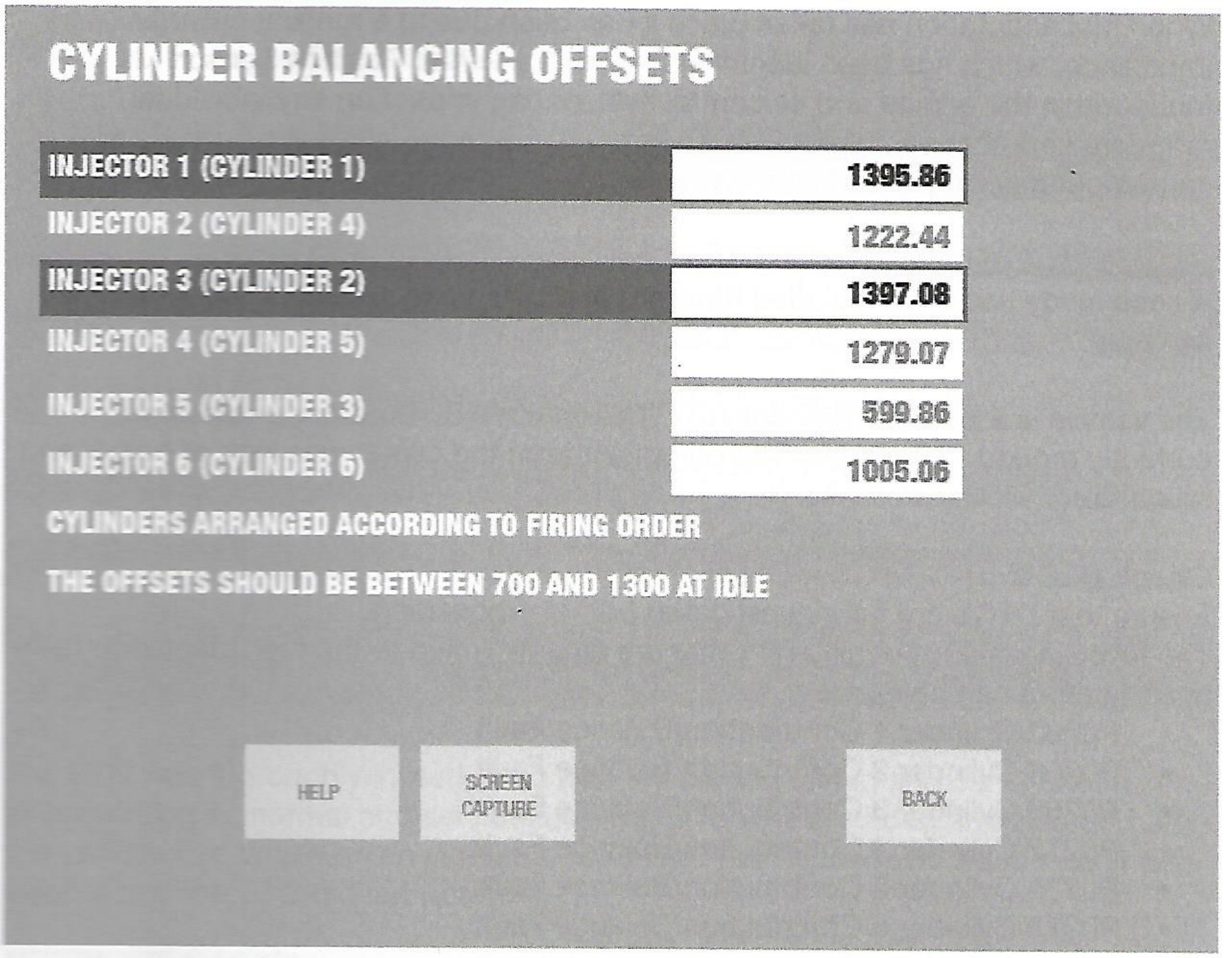
Note:

It is most likely that the cylinders with the high offsets are the cause of the fault and the low values are trying to compensate!

HOWEVER, this is not always the case...

ALWAYS carry out full diagnosis before replacing parts!

VALUES AND PARAMETERS continued...



CYLINDER BALANCING OFFSETS

INJECTOR 1 (CYLINDER 1)	1395.86
INJECTOR 2 (CYLINDER 4)	1222.44
INJECTOR 3 (CYLINDER 2)	1397.08
INJECTOR 4 (CYLINDER 5)	1279.07
INJECTOR 5 (CYLINDER 3)	599.86
INJECTOR 6 (CYLINDER 6)	1005.06

CYLINDERS ARRANGED ACCORDING TO FIRING ORDER

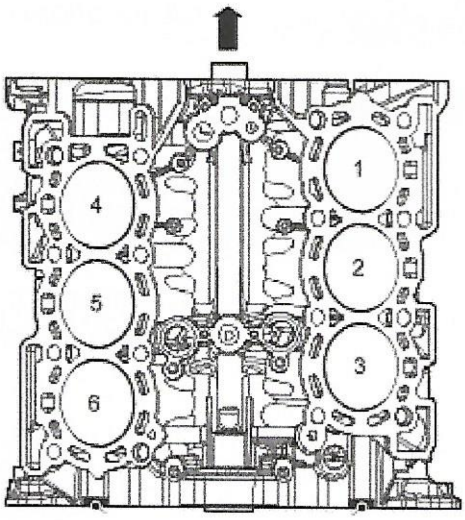
THE OFFSETS SHOULD BE BETWEEN 700 AND 1300 AT IDLE

Example of a Discovery 3 operating within 2 faulty injectors

Caution:

Land Rover cylinder identification can be confusing. Some tools do not provide cylinder numbers and some injectors are numbered 0 to 5 with 0 being injector 1!

Refer to vehicle specific diagnostic information.



FAULT DIAGNOSIS

When fuel adaptation has taken place it has been due to a running cylinder imbalance, which has been identified by the Crankshaft Position Sensor. Many faults within the engine and its control system can impact on any individual cylinders contribution, therefore it is essential that thorough fault diagnosis is carried out before any parts are ordered/fitted.

Case Study Example

A case study has been included throughout this topic to provide a real world example.

The vehicle is a 2008 Ford Focus (LT) TDCi with a 2.0L Duratorq engine and currently around 250,000km. The complaint from the owner was lack of power and rough idle.

Check DTC's

Ensure that DTC's are fully investigated before proceeding.
The following is a list of all DTC's that are directly linked to the fuel adaptation table and therefore can be ignored:

- P0263 Cylinder 1 Contribution/Balance Fault
- P0266 Cylinder 2 Contribution/Balance Fault
- P0269 Cylinder 3 Contribution/Balance Fault
- P0272 Cylinder 4 Contribution/Balance Fault
- P0275 Cylinder 5 Contribution/Balance Fault
- P0278 Cylinder 6 Contribution/Balance Fault
- P0281 Cylinder 7 Contribution/Balance Fault
- P0284 Cylinder 8 Contribution/Balance Fault
- P0287 Cylinder 9 Contribution/Balance Fault
- P0290 Cylinder 10 Contribution/Balance Fault
- P0293 Cylinder 11 Contribution/Balance Fault
- P0296 Cylinder 12 Contribution/Balance Fault

Note: *These are the generic codes, there may also be manufacturer specific codes with similar descriptions!*

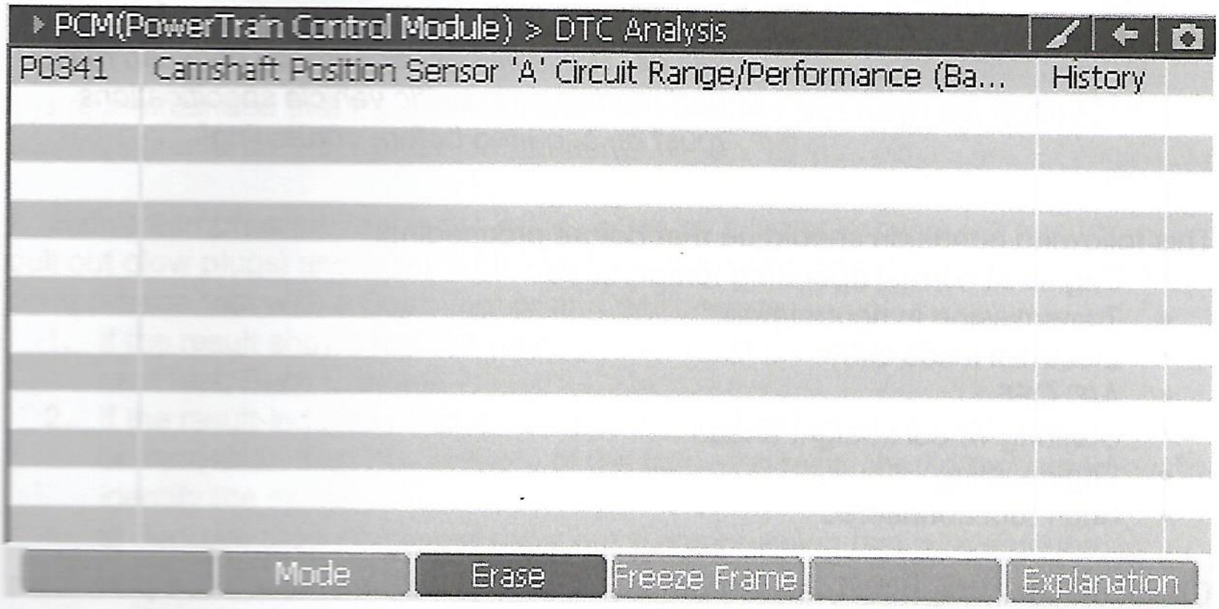
Caution: *Some manufacturers set the trigger point for the DTC setting logic much higher than the normal operating range to reduce the chances of the Malfunction Indicator Lamp (MIL) illuminating.*

The absence of a DTC does not mean that the system is within parameters!

FAULT DIAGNOSIS continued...

Case Study Example

When presented the Focus had a P0341

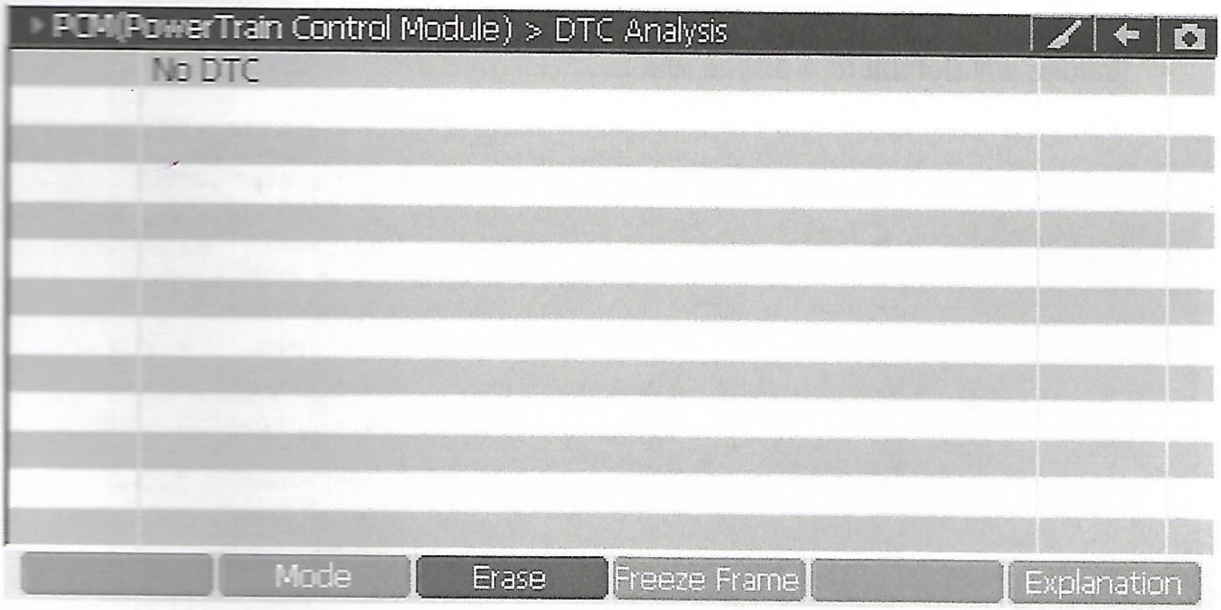


PCM(PowerTrain Control Module) > DTC Analysis

P0341 Camshaft Position Sensor 'A' Circuit Range/Performance (Ba... History

Mode
Erase
Freeze Frame
Explanation

The DTC was thoroughly investigated with the sensor, wiring and camshaft timing all presenting as normal and serviceable. The DTC was recorded and cleared before the vehicle was driven on an extended road test. During the road test the fault was evident and the DTC did not return.



PCM(PowerTrain Control Module) > DTC Analysis

No DTC

Mode
Erase
Freeze Frame
Explanation

It was concluded that the P0341 had little or no bearing on the current fault.

FAULT DIAGNOSIS continued...

Check Scan Tool Data

Note: *It is rare for the Scan Tool to provide pass/fail results or specifications for the fuel adaption values. These values vary greatly between makes and models so specific vehicle specifications must be acquired before continuing!*

This following condition should be met before proceeding:

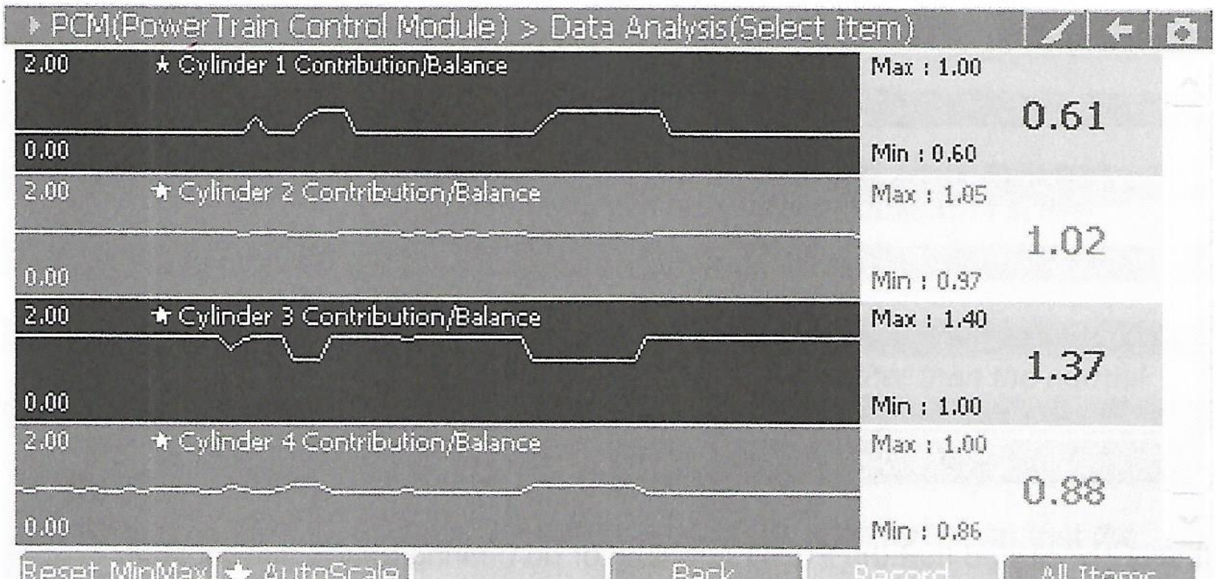
- Engine at normal operating temperature
- Transmission in neutral/park
- Electrical loads OFF
- A/C OFF
- Steering wheel straight ahead
- Engine idling
- Scan tool connected

Check the fuel adaptation values from the Scan Tool Data menu and compare them against the manufacturers specifications.

Case Study Example

The specifications for the Focus are as follows:

- Cylinder Contribution/Balance is on a 0 to 2 scale
- 1 represents the baseline (it might help to think of it as 100%)
- Ford states that: Normal operating range is 0 ± 0.25
- Values will default to 1 above idle



★ Cylinder 1 Contribution/Balance Max : 1.00 0.61 Min : 0.60
★ Cylinder 2 Contribution/Balance Max : 1.05 1.02 Min : 0.97
★ Cylinder 3 Contribution/Balance Max : 1.40 1.37 Min : 1.00
★ Cylinder 4 Contribution/Balance Max : 1.00 0.88 Min : 0.86

The Focus showed cylinders #1 and #3 were outside of parameters.

FAULT DIAGNOSIS continued...

Check cylinder compression

There are now two possible causes of the cylinder imbalance:

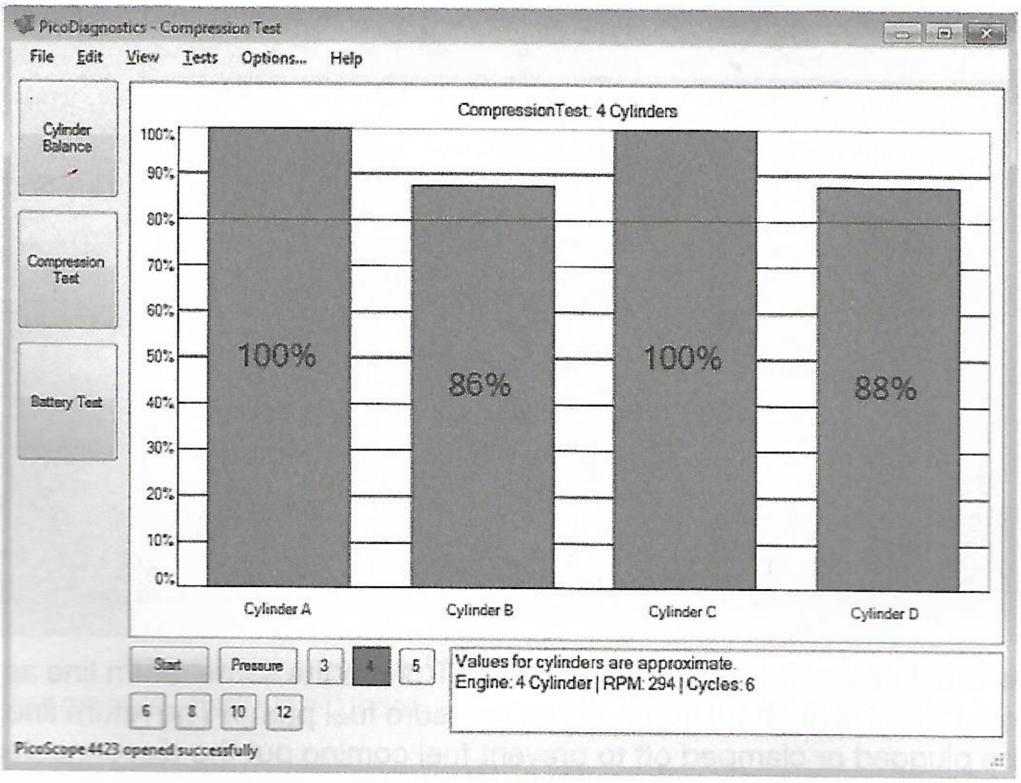
- Mechanical related failure
- Injector related failure

It is recommended that mechanical faults be checked and ruled out before continuing onto control system components.

A relative compression test is the initial option as it is noninvasive (no need to pull out glow plugs) and takes a lot less time. It may be possible to do a relative compression test with a Scan Tool or an Oscilloscope.

1. If the result shows that the relative compressions are even move on to the next test, Back Leakage
2. If the result indicates that one or more cylinders have low relative compression then one or more of the following tests should be carried out to identify the cause:
   a) Remove glow plugs and carry out a compression test with a gauge
   b) Carry out a cylinder leakage test, using a smoke machine to test for leakage can be more accurate than trying to listen for air noise.
   c) Visually inspect the valve train, valve clearances, camshaft lobe wear, valve springs, hydraulic lifters, followers and rocker arms

Case Study Example


PicoDiagnostics - Compression Test
File
Edit
View
Tests
Options...
Help
Cylinder Balance
Compression Test
Battery Test
CompressionTest: 4 Cylinders
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
100%
86%
100%
88%
Cylinder A
Cylinder B
Cylinder C
Cylinder D
Start
Pressure
3
4
5
6
8
10
12

Values for cylinders are approximate.
Engine: 4 Cylinder | RPM: 294 | Cycles: 6

PicoScope 4423 opened successfully

The Focus showed that all cylinders were in the acceptable range and above 80%

FAULT DIAGNOSIS continued...

Injector Back Leakage

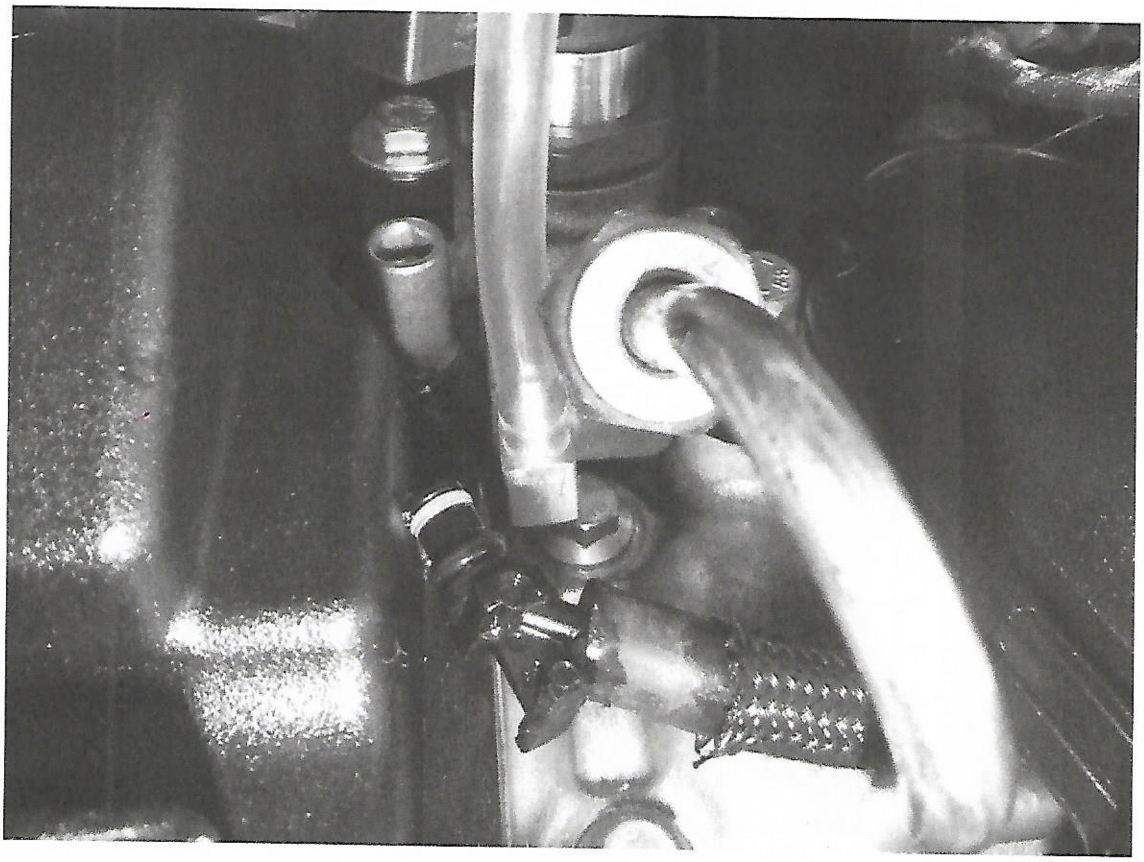
There are still a few possible causes that need to be ruled out before condemning the injector/s. The back leakage test measures the amount of fuel used to actuate each individual injector. This is a useful tool in diagnosing if any cylinder imbalance is caused by the control circuit of an injector or its nozzle.

This following condition should be met before proceeding:

- Engine at normal operating temperature
- Transmission in neutral/park
- Electrical loads OFF
- A/C OFF
- Steering wheel straight ahead
- Engine idling

To carry out the back leakage test:

1. Disconnect the injector return lines from each injector
2. Connect the back leakage test connectors to each injector



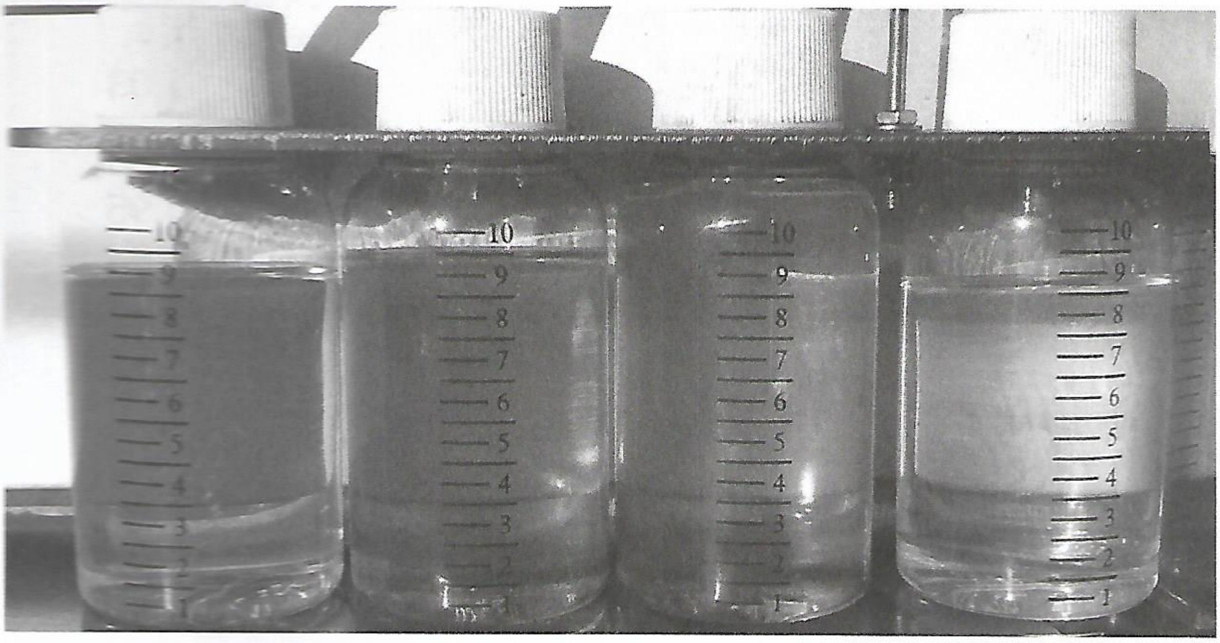
3. In most cases the injector return line is T'd into the same return line as the rail control valve (if fitted) and the high pressure fuel pump. The return line should be plugged or clamped off to prevent fuel coming out the disconnected return lines
4. Connect the back leak tester to the injectors and hang the vials from a suitable place

FAULT DIAGNOSIS continued...

5. Start the engine and allow it to idle
6. As a general rule there is no flow rate, just the comparison between the cylinders. Allow the engine to idle for at least five minutes or until one vial reaches near the top of the vial
7. If the back leakage test identifies faulty injector/s and this corresponds with one or more of the cylinders that are identified by the scan tool, then these injectors should be replaced
8. If the back leakage does not support or identify a fault with any of the fuel injectors the following conditions could be the cause and should be checked:
   a) Blocked return line between the injector and where it is T'd into the common line
   b) Blockage or restriction of the fuel injector feed pipe
   c) Intermittent wiring fault between the fuel injector and the injector driver or ECM
   d) Internal error in the ECM

Note: *It is not possible to carry out a back leakage test on some vehicles (eg. return lines within cylinder head or valve cover). If this is the case, rule out all items in step 8 in the above procedure before replacing the injector/s!*

Case Study Example



Note: the vials where on 7.0, 7.5, 10.0 & 6.5 when the test ended.
The kit was removed in order to get a clear photo and the fuel ran down the lines overfilling the vials

The back-leakage test on the Focus identified excessive back leakage on cylinder 3. This corresponds with the high cylinder contribution identified by the fuel adaptation table.

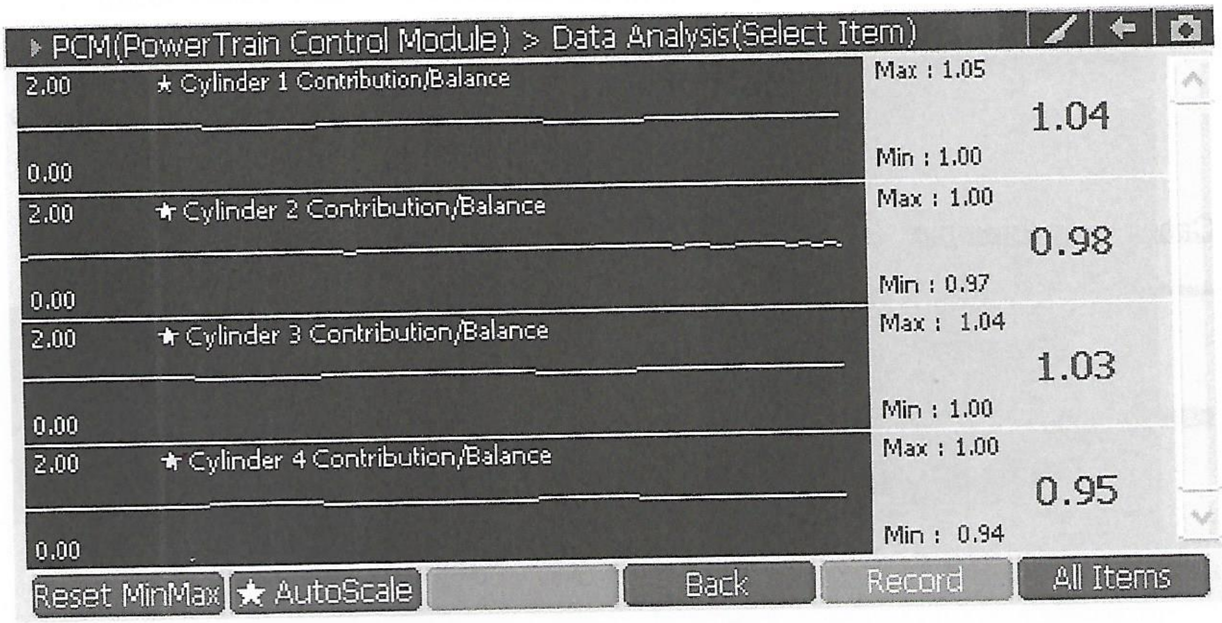
FAULT DIAGNOSIS continued...

Diagnostic Conclusion
As a general rule: if one cylinder has a large positive correction value and another cylinder has a negative value of a similar magnitude, the fault lies in the cylinder with the positive correction and the negative value is caused by the ECM trying to create balance in the running engine.

Case Study Example
The scan tool cylinder contributions identified that the contributions of cylinder #1 was low and cylinder #3 was high, while the back leakage only identified an issue with injector #3.

Based on these values and the understanding that the low cylinder #1 contribution could be in response to the fault on cylinder #3 it was decided to replace the #3 injector.

The following cylinder contributions were recorded after the injector replacement:



PCM(PowerTrain Control Module) > Data Analysis(Select Item)

2.00 ★ Cylinder 1 Contribution/Balance
0.00
Max : 1.05
1.04
Min : 1.00

2.00 ★ Cylinder 2 Contribution/Balance
0.00
Max : 1.00
0.98
Min : 0.97

2.00 ★ Cylinder 3 Contribution/Balance
0.00
Max : 1.04
1.03
Min : 1.00

2.00 ★ Cylinder 4 Contribution/Balance
0.00
Max : 1.00
0.95
Min : 0.94

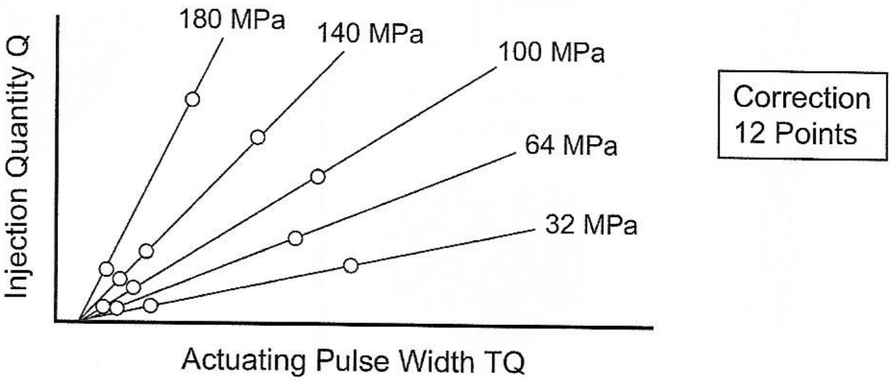
FAULT DIAGNOSIS continued...

Caution: *Contrary to popular belief, cylinder balance cannot take the place of injector coding!*

It is not uncommon to find injectors that have been fitted without being coded, because some owners and technicians believe that the fuel adaption tables can compensate for the changes.

However, for most vehicles the adaption is only applicable to idle and only at idle fuel pressure (30-40MPa).

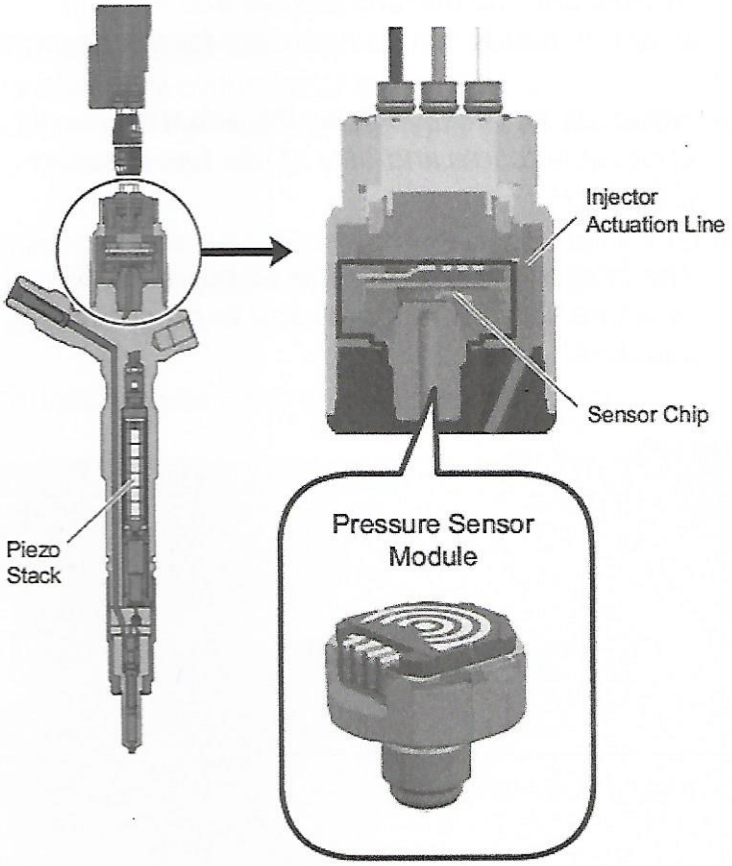
The image below shows the 12 points on 5 pressure settings that are used to program injectors!

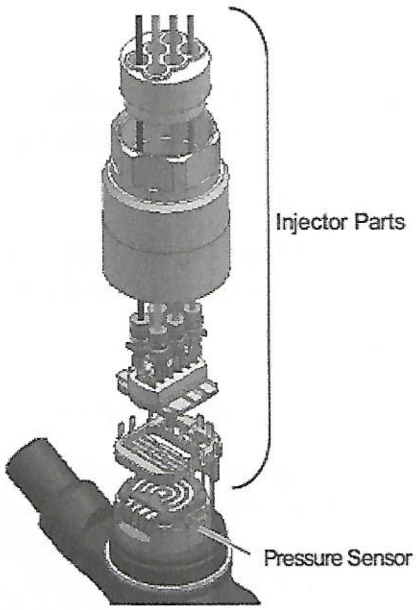


Therefore, coding new/replacement injectors is essential!

FUTURE DEVELOPMENTS

These new fuel injectors have been designed and built by Denso. Coined intelligent-Accuracy Refinement Technology (i-ART) these injectors incorporate an integrated pressure sensor which monitors the changing pressures in the back leakage circuit allowing the ECM to monitor actual fuel injection quantity under ALL conditions!


Injector
Actuation Line
Sensor Chip
Pressure Sensor
Module
Piezo
Stack


Injector Parts
Pressure Sensor

The injectors have been fitted in all Brazilian delivered Hilux's with 1KD engines since April 2012. There is no clear indication of global release and how they perform in Brazil will determine their future use. It is suggested that the technology might be introduced globally when the EURO 6c legislation comes into force in the EU in 2017.

Section v

Common Rail Diesel Exhaust Smoke Diagnosis

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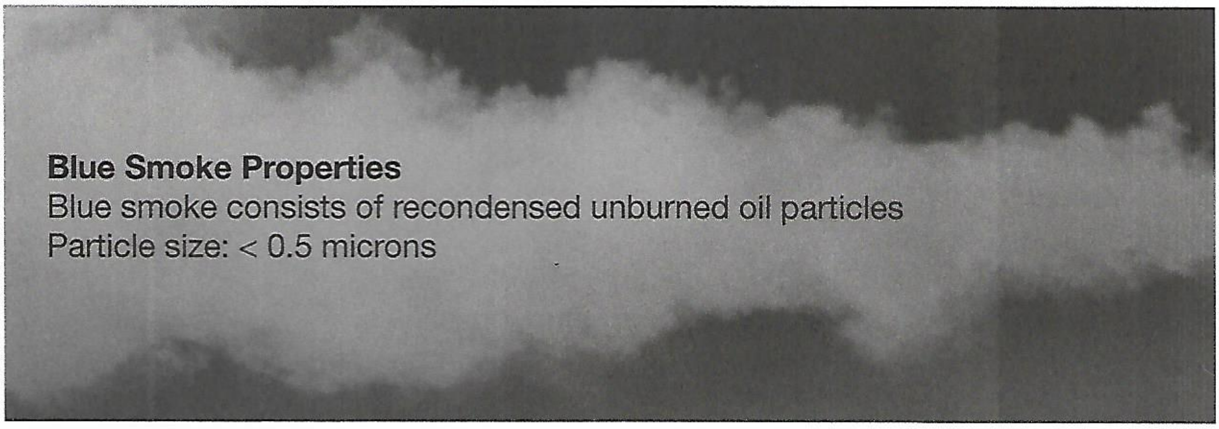
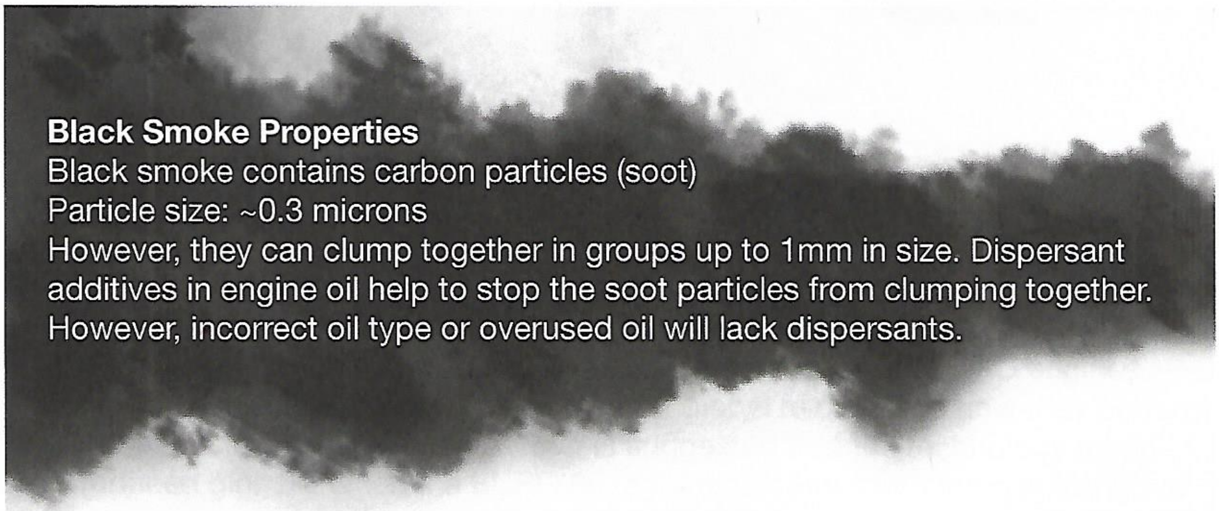
INTRODUCTION

Exhaust smoke from diesel vehicles can tell a story and when combined with other diagnostic information it can become a useful diagnostic tool. This information is only suitable for diesel vehicles that DO NOT have a diesel exhaust after treatment (DEA) system. As vehicles with DEA systems are still a minority in the Australian and New Zealand carparc, understanding the different causes of exhaust smoke is essential.

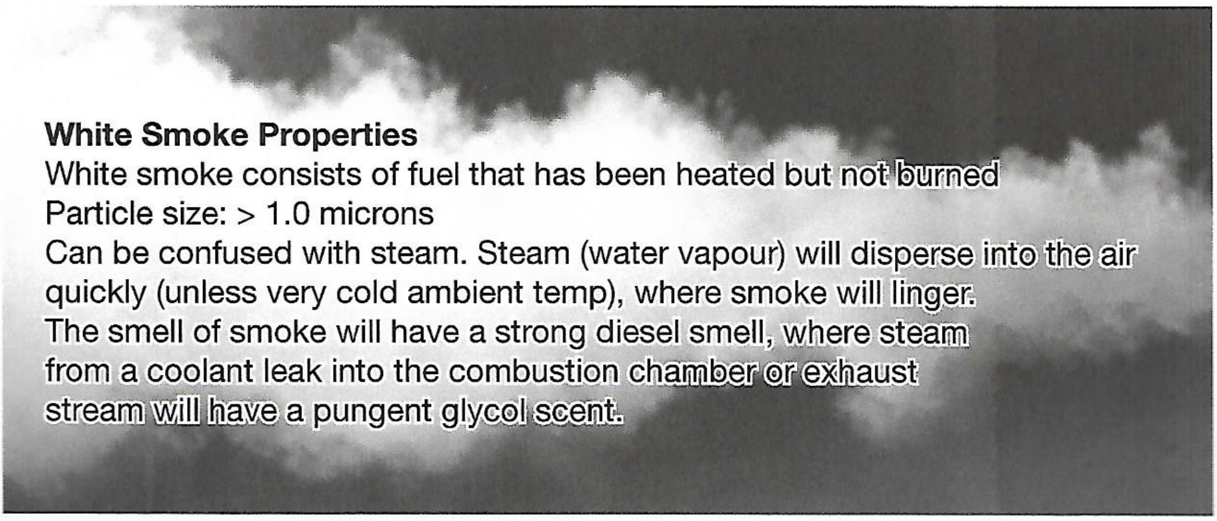
CRD EXHAUST SMOKE COMPOSITION



Blue Smoke Properties
Blue smoke consists of recondensed unburned oil particles
Particle size: < 0.5 microns



Black Smoke Properties
Black smoke contains carbon particles (soot)
Particle size: ~0.3 microns
However, they can clump together in groups up to 1mm in size. Dispersant additives in engine oil help to stop the soot particles from clumping together. However, incorrect oil type or overused oil will lack dispersants.



White Smoke Properties
White smoke consists of fuel that has been heated but not burned
Particle size: > 1.0 microns
Can be confused with steam. Steam (water vapour) will disperse into the air quickly (unless very cold ambient temp), where smoke will linger.
The smell of smoke will have a strong diesel smell, where steam from a coolant leak into the combustion chamber or exhaust stream will have a pungent glycol scent.

EXHAUST SMOKE DIAGNOSIS

	Blue Smoke	Black Smoke	White Smoke
Problem	Oil entering the combustion chamber	Carbon particles form when combusting fuel runs out of oxygen and exits the exhaust only partially burned	No combustion is occurring in at least one cylinder
Causes	Incorrect engine oil	Blocked air filter or intake	Very low compression in at least one cylinder
	Overfilled with oil	High exhaust back-pressure	Severe injector nozzle leak/dribble
	Over-oiled (eg. K&N type) air filter	Valve timing out	Diesel added to DEF tank (if fitted)
	Worn engine	EGR inoperative	
	Turbocharger seals	Control fault (limp mode)	
	Crankcase ventilation Fault	Low boost pressure	
	Turbocharger oil return blocked	Worn fuel injector/s	
		Low compression	
		Pre-heating fault (only when not fully warmed)	
		DPF failure (if fitted)	

How smoke effects Diesel Exhaust After-treatments (DEA's)

Blue Smoke

Smoke from burning oil contains ash, over time the ash will clog the Diesel Particulate Filter (DPF), which will require it to be serviced or replaced. If a DPF fills with ash over a short period of time, carry out diagnosis on the systems outlined in the blue smoke table.

Black Smoke

Smoke from excessive soot will cause the need for excessive DPF regenerations and in more severe cases the DPF will not be able to keep up and will regularly request driver initiated and service regenerations. If experiencing these conditions, carry out diagnosis on the systems outlined in the black smoke table.

Note: *If a vehicle is fitted with a DPF and is blowing black smoke, it almost certainly has a broken or melted substrate!*

White Smoke

White smoke consists of non-combusted fuel particles, as the diesel exhaust stream should be fairly rich with oxygen it will normally ignite in the Diesel Oxidising Catalyst (DOC) causing runaway temperatures in the DOC and DPF. This condition can be responsible for melting components such as exhaust sensors and the DOC and DPF substrates. If experiencing these conditions, carry out diagnosis on the systems outlined in the white smoke table.

Note: *If a vehicle is fitted with SCR and is blowing white smoke it may have diesel in the DEF tank!*

Section vi

Diagnostic Tips

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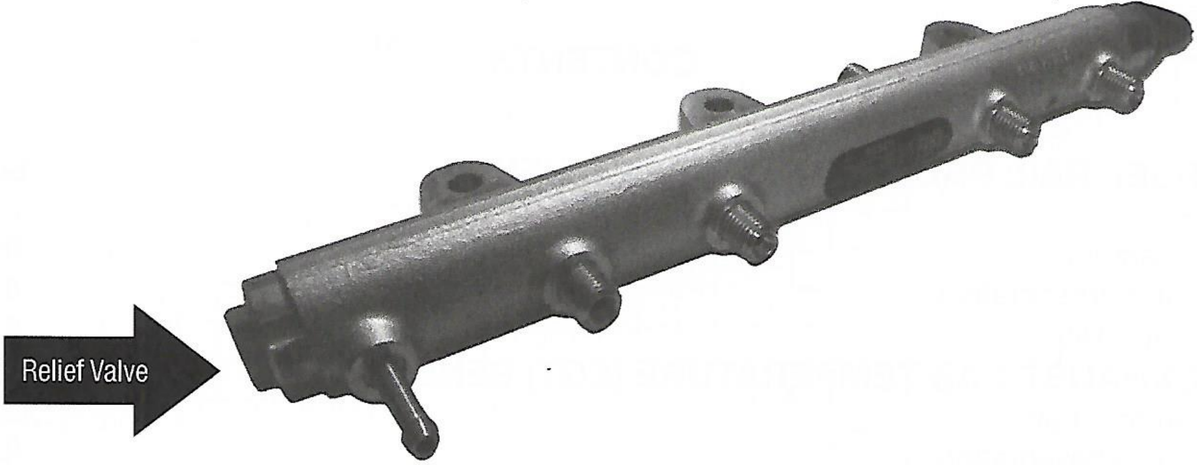
FUEL RAIL PRESSURE RELIEF VALVES

Purpose

The Fuel Rail Pressure Relief Valve is a mechanical pressure limiting valve that provides a safety mechanism against over pressurisation of the high pressure fuel system should the high pressure fuel pump undergo a failure that causes maximum output. The pressure is set a significant amount (usually around 50MPa) higher than normal maximum operating pressure).



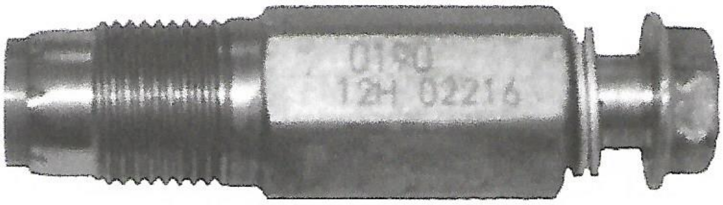
Bosch common rail (BT-50/Ranger) with Fuel Rail Pressure Relief Valve in the foreground

Operation

Once the rail pressure reaches the opening pressure of the Fuel Rail Pressure Relief Valve it will open and redirect fuel into the return system. The valve will remain open until the rail pressure drops to the closing pressure.

An example of operation is the relief valve found on vehicles running the Denso HP3 high pressure fuel pump:

- Normal maximum operating pressures are 160-180MPa
- Fuel Rail Pressure Relief Valve opening pressure is 230MPa
- Fuel Rail Pressure Relief Valve closing pressure is 50MPa



Denso Fuel Rail Pressure Relief Valve

Fault Presentation

A faulty valve will normally present with the following characteristics:

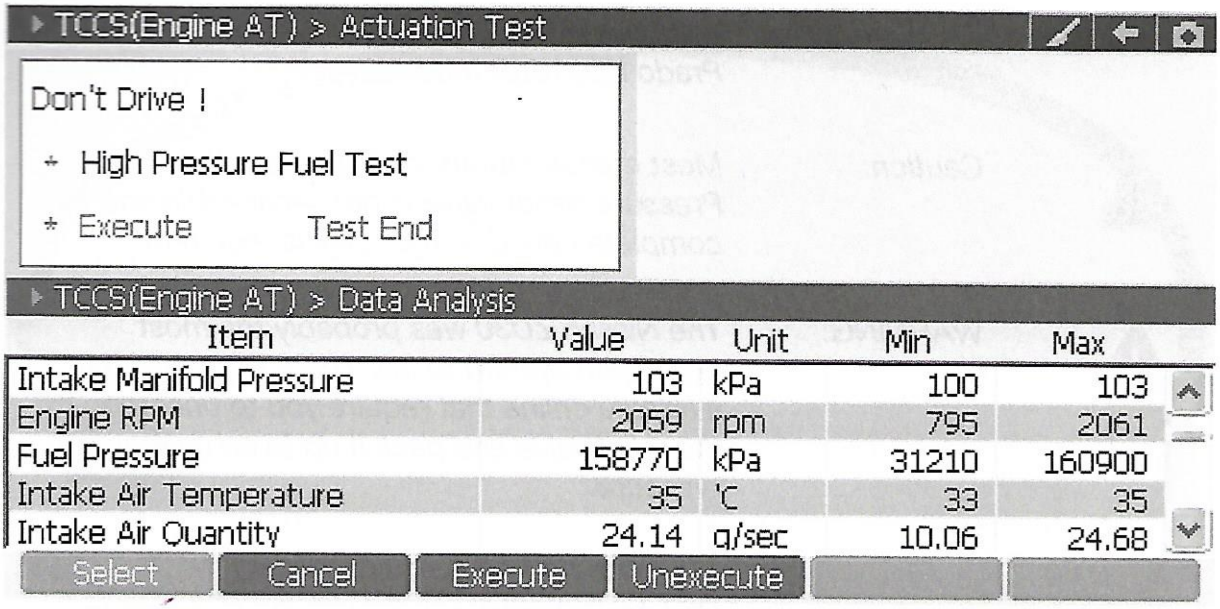
- No change to idle
- No change to low RPM light acceleration
- An abrupt and significant loss of performance
- Logging of low pressure DTC's
- If monitoring the Scan Tool Data the rail pressure value will suddenly drop and correspond with the loss of performance
- After a short idle the valve will close and the cycle will reset

FUEL RAIL PRESSURE RELIEF VALVES continued...

Diagnosis

To diagnose a faulty Fuel Rail Pressure Relief Valve follow this procedure:

- Disconnect the fuel return hose from valve
- Clamp off the hose to prevent spillage
- Connect a length of clear hose onto the valve, clamp it firmly and direct the hose into a fuel storage container
- Connect a compatible scan tool
- Start the engine
- Navigate the scan tool to the Actuation Test menu the select High Pressure Fuel Test
- While watching the clear hose as close to the valve as possible, command the High Pressure Fuel Test



TCCS(Engine AT) > Actuation Test

Don't Drive !

+ High Pressure Fuel Test

+ Execute Test End

TCCS(Engine AT) > Data Analysis

Item	Value	Unit	Min	Max
Intake Manifold Pressure	103	kPa	100	103
Engine RPM	2059	rpm	795	2061
Fuel Pressure	158770	kPa	31210	160900
Intake Air Temperature	35	°C	33	35
Intake Air Quantity	24.14	g/sec	10.06	24.68

- The scan tool will increase the RPM (usually to around 2,000 RPM) so that the pump can generate enough pressure to reach normal maximum operating pressure
- If ANY fuel escapes from the Fuel Rail Pressure Relief Valve it is faulty and must be replaced
- End the Scan Tool test and allow the engine to idle

Denso common rail (Nissan YD25) with Fuel Rail Pressure Relief Valve on the right end

FUEL RAIL PRESSURE RELIEF VALVES continued...

Note: *Procedure only suitable for systems with individual Pressure Relief Valves!*

Toyota KD engine
Euro 3 – Single Pressure Control
Pressure Relief Valve

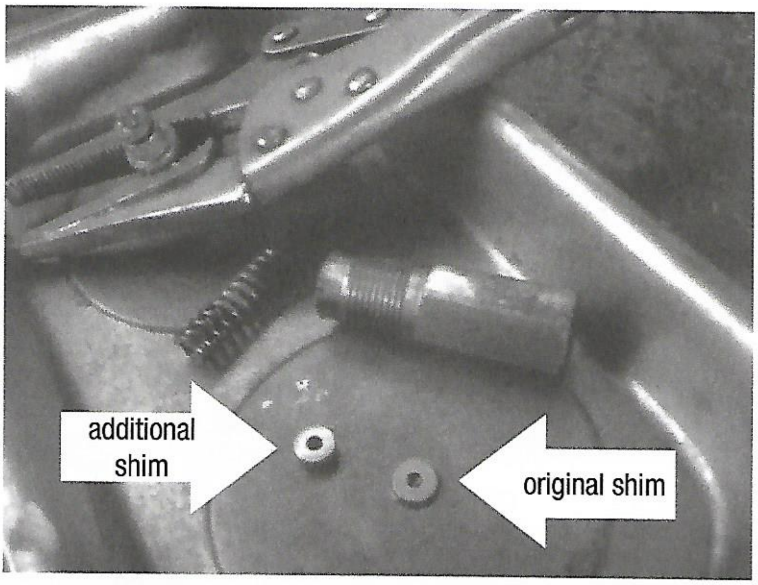
Toyota KD engine
Euro 4 – Dual Pressure Control
Rail Pressure Control with Relief Valve

EURO 4 1KD engines are only found in Toyota Prado KDJ150R models!

Caution: *Most manufacturers state that the Fuel Rail Pressure Relief Valve is not serviceable and a complete new Common Rail is required!*

WARNING: *The Nissan ZD30 was probably the most prominent system to fail. There are shim kits available online that require you to uncrimp the relief valve and pack it up to an unknown pressure.*

THIS PROCEDURE IS STRONGLY DISCOURAGED!



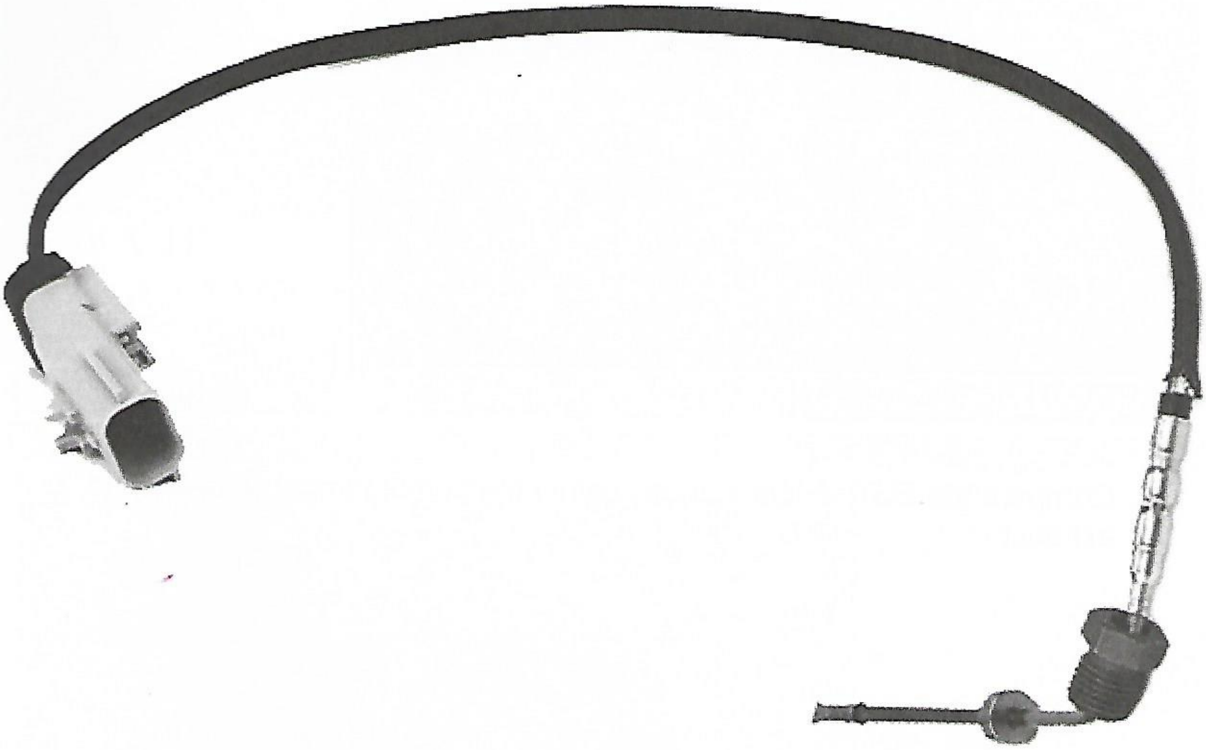
EXHAUST GAS TEMPERATURE (EGT) SENSORS

Introduction

For vehicles which Diesel Exhaust After-treatment (DEA) systems, the monitoring of the exhaust gas temperature is essential.
Vehicles can use between 1 and 4 sensors:

- Turbo-EGT – directly before turbine
- Pre-EGT – before Oxidising Catalyst (OC)
- Main-EGT – after OC & before DPF
- Post-EGT – after DPF

Note: *For vehicles with multiples sensors, the sensors are normally the same, although pigtail lead length and connector may vary!*



Fault Presentation

Some vehicles may not bring on the Malfunction Indicator Lamp (MIL) or log DTC's if an exhaust temperature sensor fails. In some vehicles a nominal value may be assigned while others may default to the last known value.

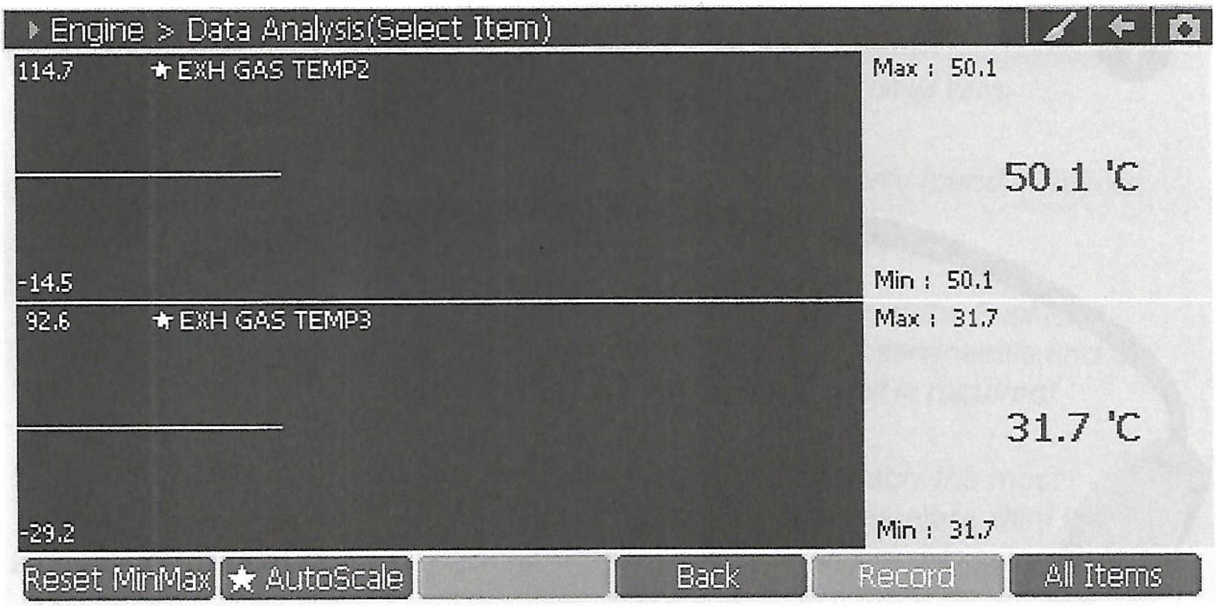
This may be problematic because most vehicles will only carry out passive DPF regenerations at temperatures below 150°C. This will usually lead to the DPF malfunction lamp illuminating in the instrument cluster.

EXHAUST GAS TEMPERATURE (EGT) SENSORS continued...

Diagnosis

The easiest method is to monitor the exhaust gas temperatures from cold start.

1. Leave the vehicle to rest (preferably overnight). This allows the sensors to 'soak' meaning that heat should be disbursed evenly across all sensors
2. Connect a compatible Scan Tool
3. Turn the ignition ON
4. Select all exhaust gas temperature sensors from the data list
5. After an overnight rest all sensor should read a similar value



114.7 ★ EXH GAS TEMP2 -14.5

Max : 50.1

50.1 'C

Min : 50.1

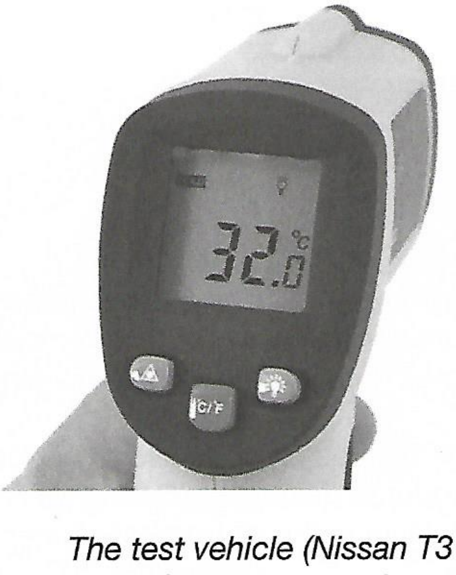
92.6 ★ EXH GAS TEMP3 -29.2

Max : 31.7

31.7 'C

Min : 31.7

6. Compare the EGT sensor values against the actual temperature of the exhaust

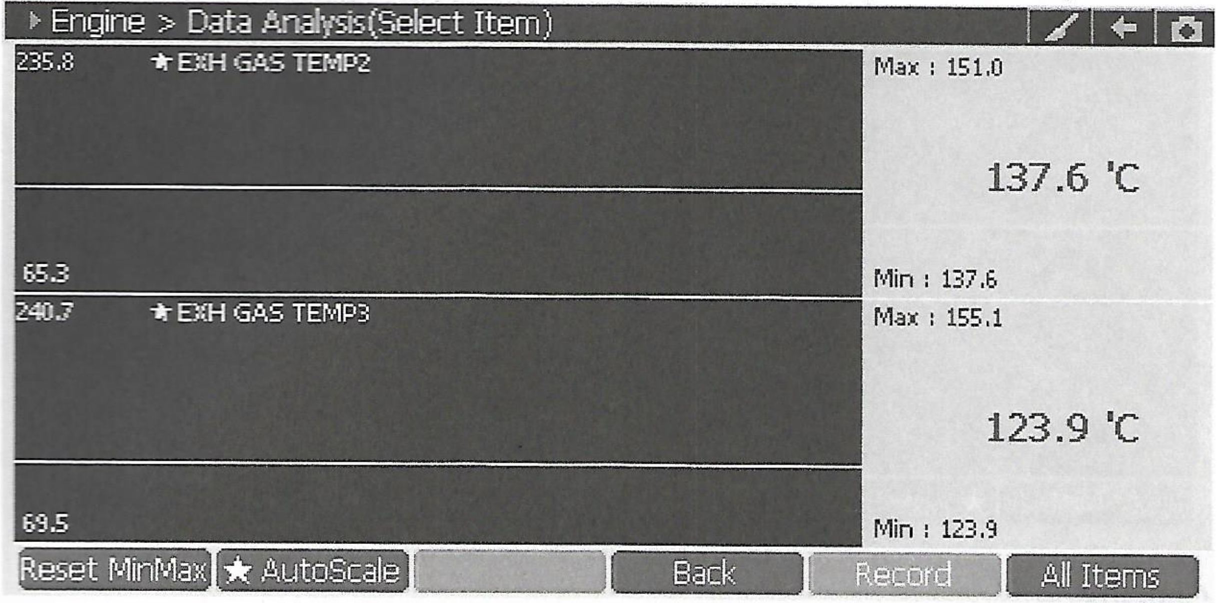


Note: *The test vehicle (Nissan T31 X-trail with M9R engine) had a slightly inaccurate EGT Sensor #2, as it was reading 18°C above actual temperature.*

EGT Sensor #1 is not provided in the data list!

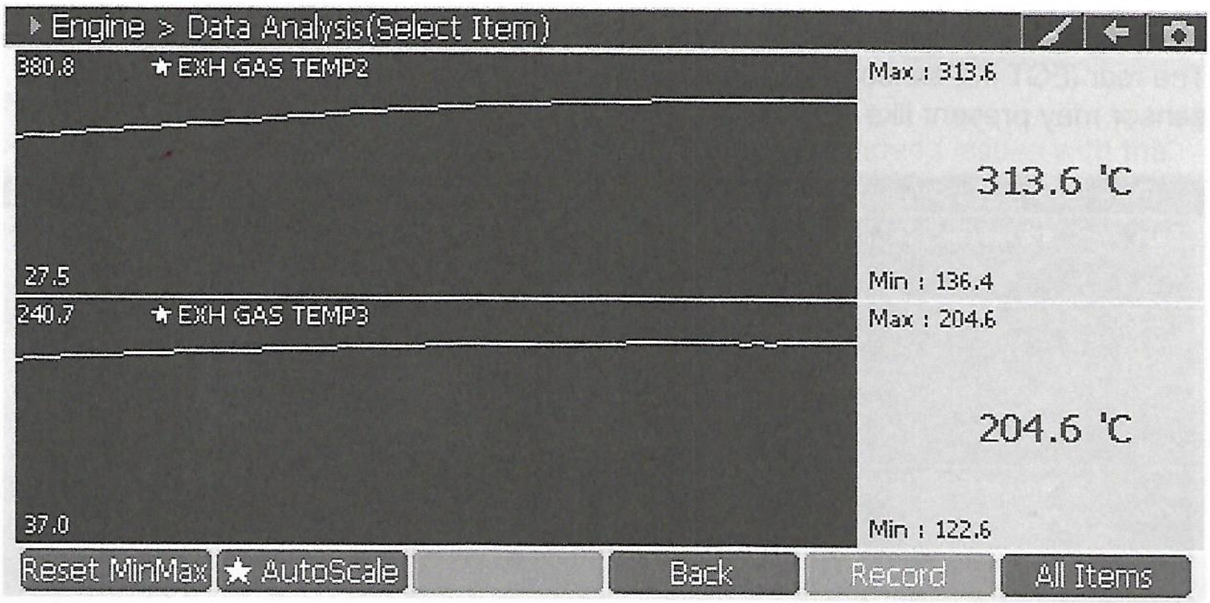
EXHAUST GAS TEMPERATURE (EGT) SENSORS continued...

7. Start the engine and allow it to idle up to normal operating temperature
8. Exhaust gas temperatures should rise steadily with the sensors closest to the engine warming up slightly quicker than the one behind


Engine > Data Analysis(Select Item)
Reset MinMax
AutoScale
Back
Record
All Items

```
235.8   EXH GAS TEMP2     Max : 151.0
                          137.6 'C
65.3                      Min : 137.6
240.7   EXH GAS TEMP3     Max : 155.1
                          123.9 'C
69.5                      Min : 123.9
```

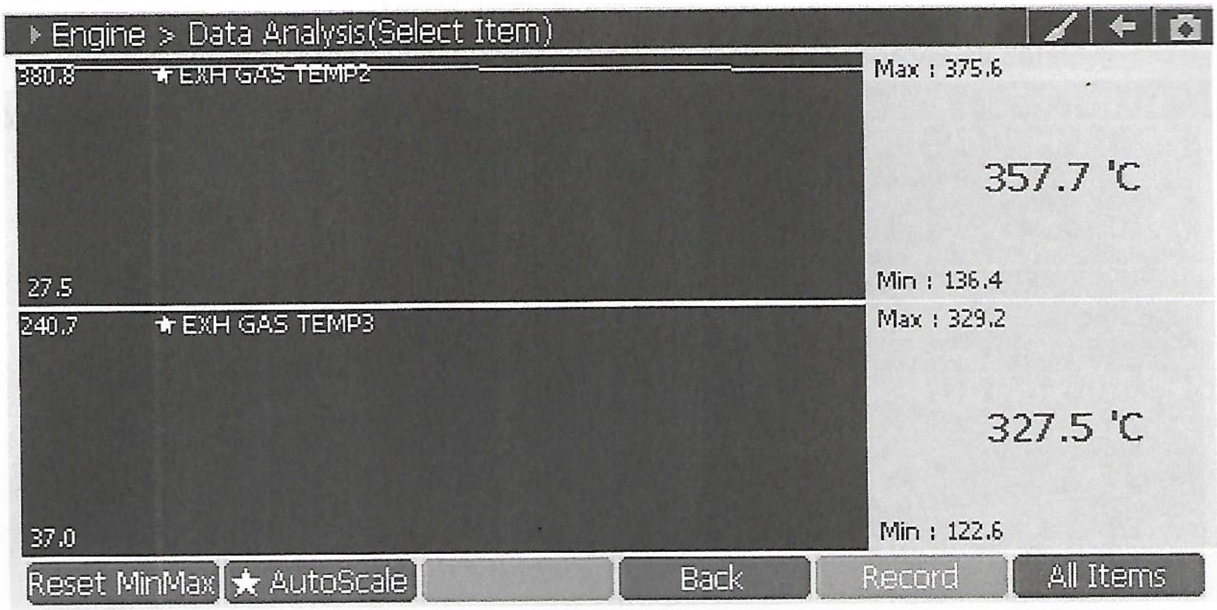
9. Hold the engine at 3,000 RPM for one minute
10. EGT's should rise further with the sensors closest to the engine warming up slightly quicker than the one behind


Engine > Data Analysis(Select Item)
Reset MinMax
AutoScale
Back
Record
All Items

```
380.8   EXH GAS TEMP2     Max : 313.6
                          313.6 'C
27.5                      Min : 136.4
240.7   EXH GAS TEMP3     Max : 204.6
                          204.6 'C
37.0                      Min : 122.6
```

EXHAUST GAS TEMPERATURE (EGT) SENSORS continued...

11. Allow the engine to idle for a couple of minutes, the EGT's should stabilise


Engine > Data Analysis(Select Item)

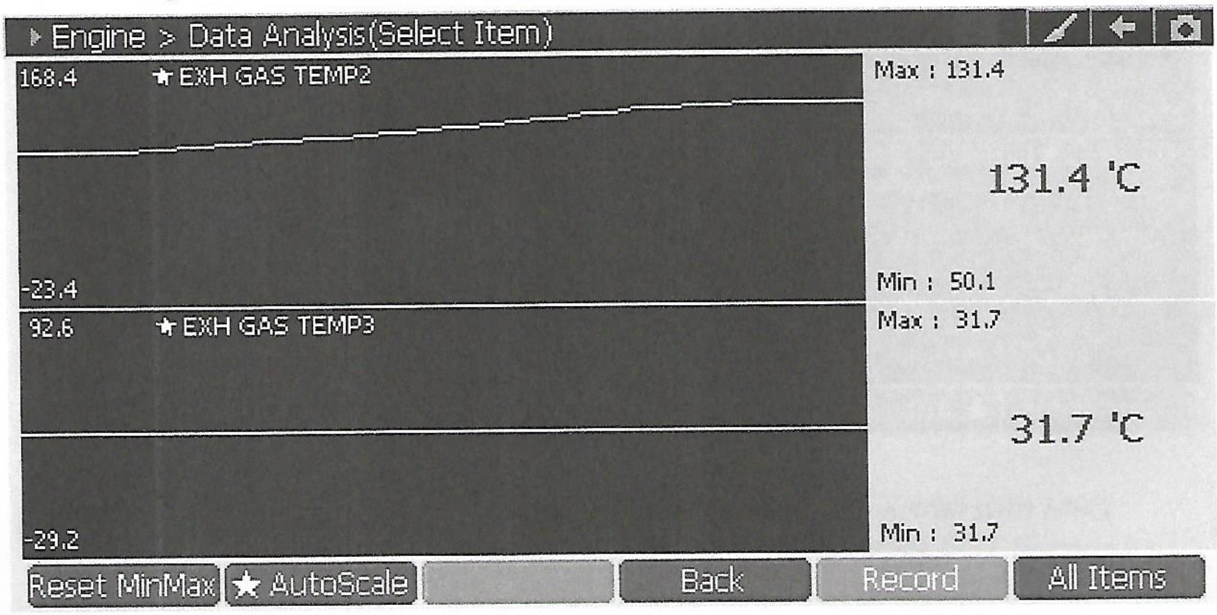
★ EXH GAS TEMP2
Max : 375.6
357.7 'C
Min : 136.4

★ EXH GAS TEMP3
Max : 329.2
327.5 'C
Min : 122.6

380.8
27.5
240.7
37.0
Reset MinMax
★ AutoScale
Back
Record
All Items

Conclusion
Exhaust gas temperatures are generated within the engine and exhaust flow also affects warm up time. It is expected that the further down stream the slower the response *(this is evident in step 10)*. However, on cold and hot soak situations the temperatures should equalise *(this is evident in items 5, 8 & 11)*.

Fault example
The rear (EGT #3) sensor was disconnected to provide an example of what a faulty sensor may present like.


Engine > Data Analysis(Select Item)

★ EXH GAS TEMP2
Max : 131.4
131.4 'C
Min : 50.1

★ EXH GAS TEMP3
Max : 31.7
31.7 'C
Min : 31.7

168.4
-23.4
92.6
-29.2
Reset MinMax
★ AutoScale
Back
Record
All Items

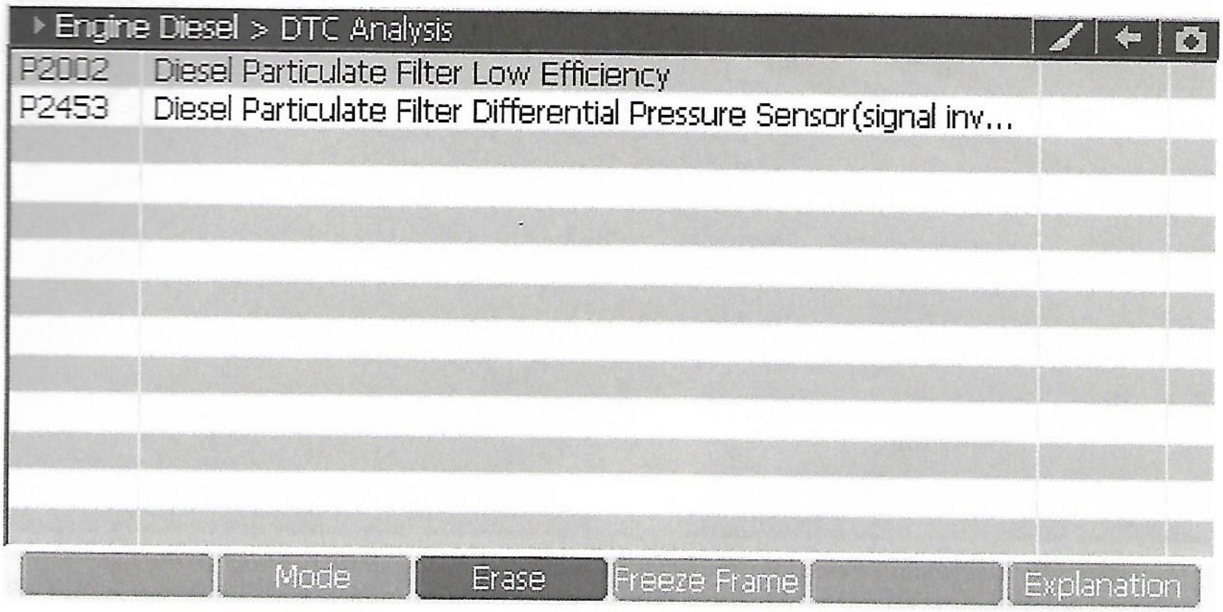
DIFFERENTIAL PRESSURE SENSOR HOSES

Introduction

We at Auto-Tech are always stressing the importance of carrying out a visual inspection as part of the initial basic inspection *(see: Diagnostic Flow Chart on page 52)*. This example is of a 2007 Holden Captiva 2.0L diesel. It had been to two workshops and the owner had persisted with the DPF warning light coming on intermittently for a few weeks.

DTC Check

On arrival the DTC's were checked:

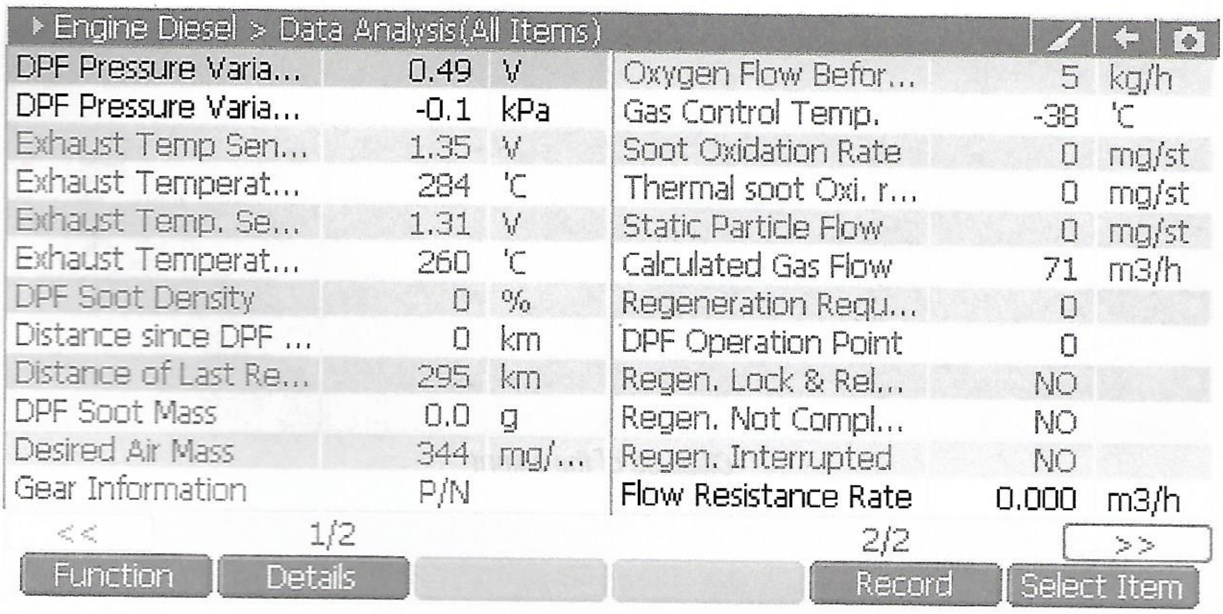


Engine Diesel > DTC Analysis

P2002	Diesel Particulate Filter Low Efficiency
P2453	Diesel Particulate Filter Differential Pressure Sensor(signal inv...

Scan Tool Data

A quick look at the scan tool data, verified that there were indeed issues with the pressure sensor values. There was no soot loading after 295km. Typically, after this distance the soot loading should be about 30-50% of its capacity.



Engine Diesel > Data Analysis(All Items)

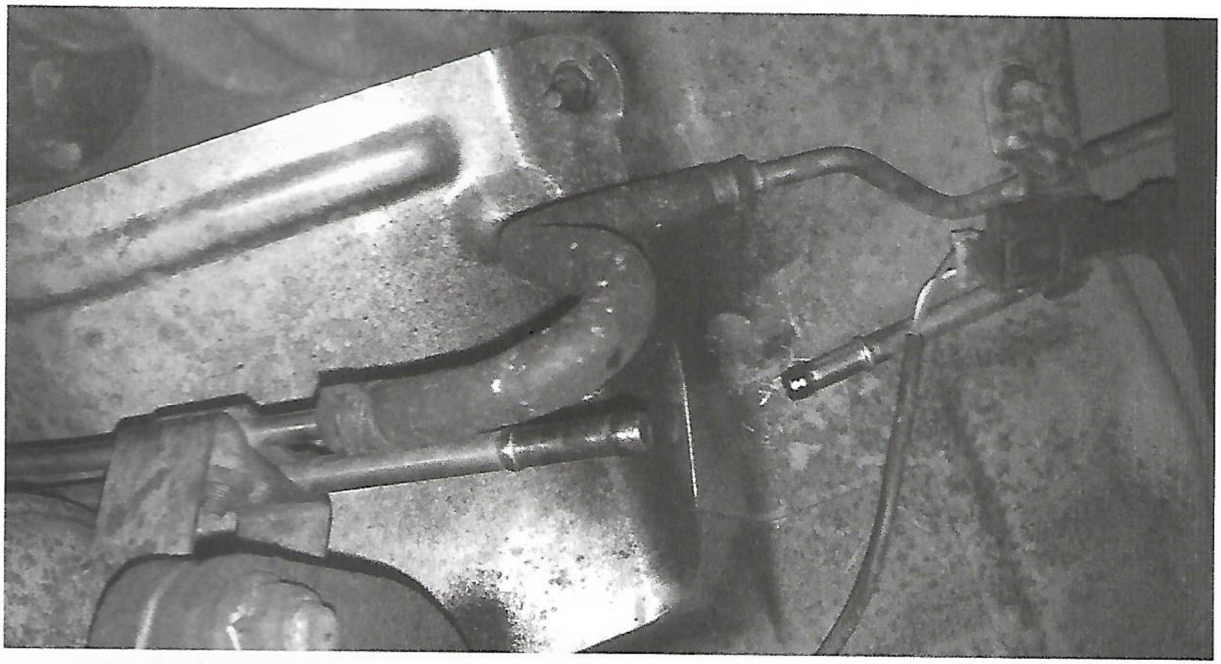
DPF Pressure Varia...	0.49	V	Oxygen Flow Befor...	5	kg/h
DPF Pressure Varia...	-0.1	kPa	Gas Control Temp.	-38	'C
Exhaust Temp Sen...	1.35	V	Soot Oxidation Rate	0	mg/st
Exhaust Temperat...	284	'C	Thermal soot Oxi. r...	0	mg/st
Exhaust Temp. Se...	1.31	V	Static Particle Flow	0	mg/st
Exhaust Temperat...	260	'C	Calculated Gas Flow	71	m3/h
DPF Soot Density	0	%	Regeneration Requ...	0	
Distance since DPF ...	0	km	DPF Operation Point	0	
Distance of Last Re...	295	km	Regen. Lock & Rel...	NO	
DPF Soot Mass	0.0	g	Regen. Not Compl...	NO	
Desired Air Mass	344	mg/...	Regen. Interrupted	NO	
Gear Information	P/N		Flow Resistance Rate	0.000	m3/h

DIFFERENTIAL PRESSURE SENSOR HOSES continued...

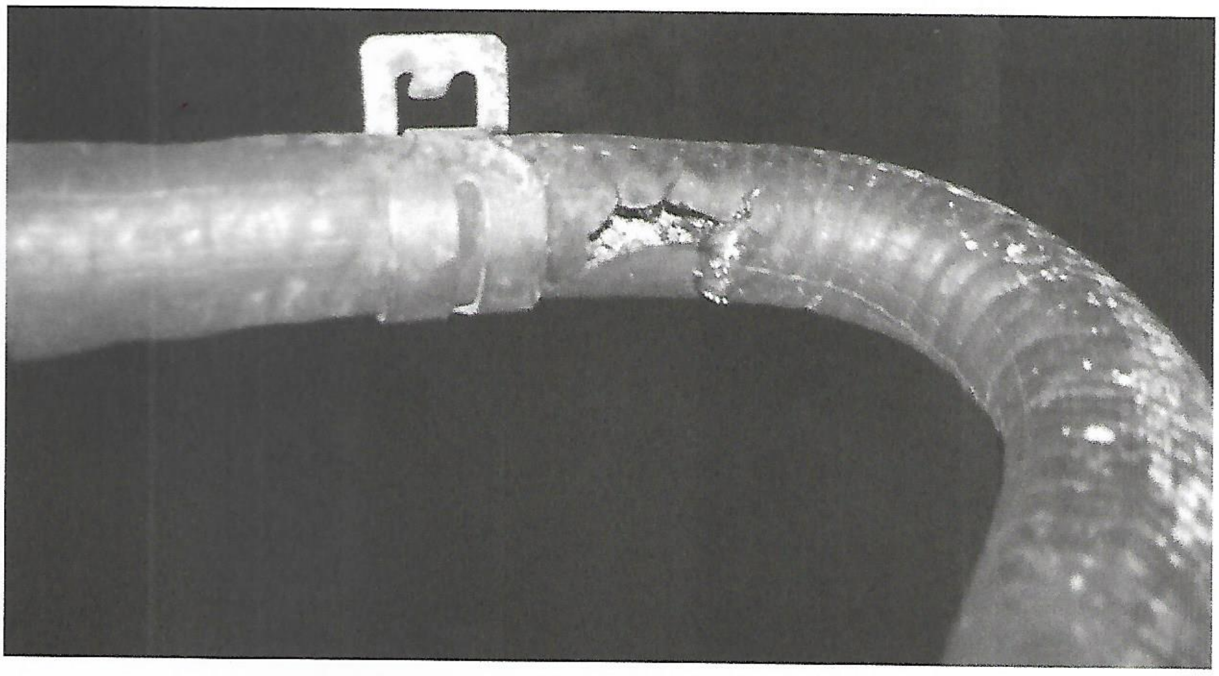
Visual Inspection

The under bonnet components were visually inspected including the differential pressure sensor. The vehicle was then raised in order to inspect the DPF components on the underside of the vehicle.

There was evidence of a possible fault immediately visible:



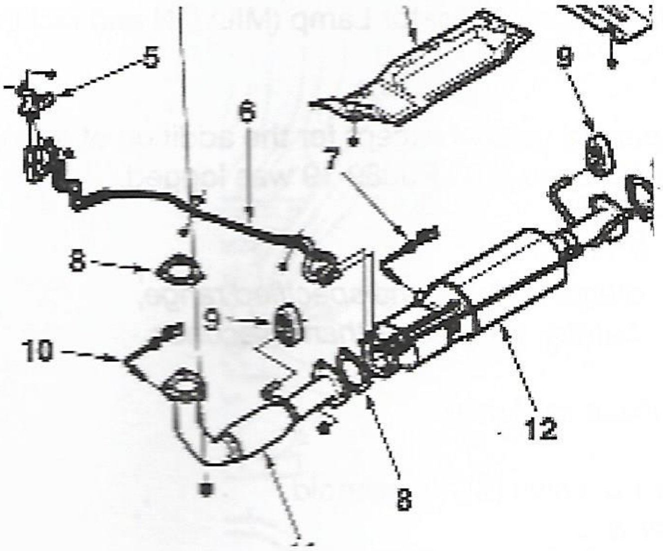
No, the hose wasn't missing! The evidence is the patch of soot on the floor of the car.



Close up of the culprit

DIFFERENTIAL PRESSURE SENSOR HOSES continued...

Repair
The hose is only available from Holden as a complete unit including two pipes, four hoses and clamps similar to the item pictured below



#5 - DPF Pressure Sensor
#6 - DPF Pressure Sensor Hose
#12 DPF

Example of hose assembly

An alternative is to purchase a suitable silicon hose (similar to a small section turbo hose). The following hose types exceed the original rubber specifications and should be available through suppliers of aftermarket silicon turbo hoses:

- Tygon Floran Severe Environment Tubing (F-5500-A)
- Duralast High Temperature Black Silicon Hose
- High Temperature Black Aramid Silicon Hose

The Captiva has 2 x 8mm ID and 2 x 6mm ID hoses (it was the 8mm exhaust end that failed).

Because the ECM has not been receiving accurate pressure readings it is important to take the vehicle for an extended road test. This allows the ECM to learn the current state of the DPF soot loading and to carry out an active regeneration.

Note: *In some cases it may be necessary to carry out a service regeneration, this will depend on how long the system has been malfunctioning and the soot loading!*

FUEL RETURN PRESSURE CASE STUDY

This fault may be specific to this particular vehicle but it sets out a very good diagnostic scenario.

The vehicle is a 2013 Holden RG Colorado with a 2.8L diesel engine. It was presented at a workshop with the Malfunction Indicator Lamp (MIL) ON and lacking power.

A visual inspection of the vehicle appeared normal except for the addition of a long range fuel tank. The DTC's were checked and DTC P0089 19 was logged.

> *DTC P0089 19*
> *The ECM detects the signal voltage is above the specified range, but not necessarily a short to battery, for greater than 2 seconds.*

Holden provide the following list of possible causes:

- Restricted fuel supply line
- High resistance in Suction Control Valve (SCV) solenoid
- Excessive fuel injector return flow

Holden's diagnostic procedure for this directs the technician through a series of tests that ultimately results in the fitment of a new SCV, on the assumption of an internal mechanical failure.

Note: *Oscilloscope diagnosis of the SCV would have shown that the current draw was not concurrent with a sticking valve!*

On the vehicle, the fuel rail pressures were monitored in the scan tool data.

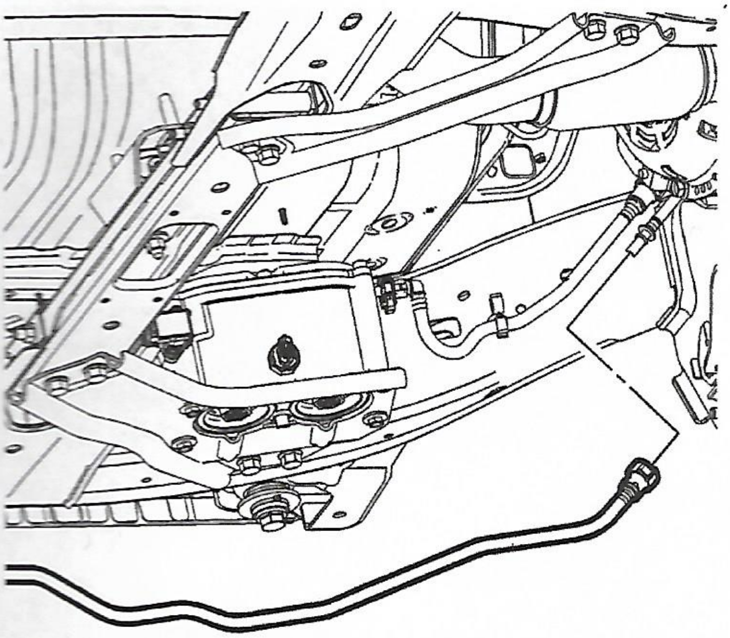
- Fuel rail pressure @ idle 50MPa at idle (specification is 30MPa)
- After driving fuel pressure would slowly drop down from 100MPa to 50MPa. This is not what would normally be found in normal operation or typical to a faulty SCV (although not enough to rule it out).

Note: *The technician responsible for the diagnosis of this vehicle realised that the prescribed diagnostic procedure did not allow for the long range tank modification and decided to rule out the modification as the cause of the fault before condemning the SCV!*

The fuel supply to the High Pressure Fuel Pump and SCV were found serviceable delivering well over the required 1.2L per 30 seconds.

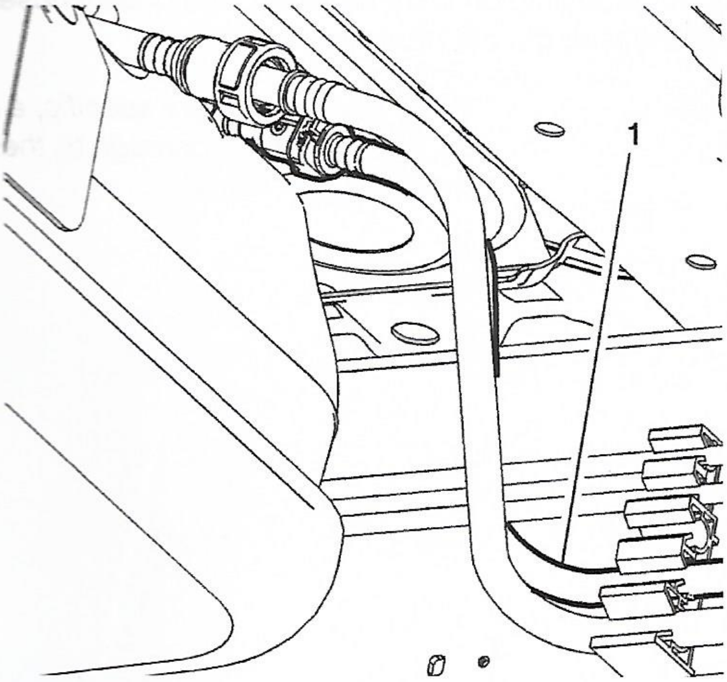
FUEL RETURN PRESSURE CASE STUDY continued...

The fuel return back pressure was then checked at the quick release coupling located directly under the engine and was found to be 170 kPa.



As with all piezo injectors a return back pressure is required for correct injector operation, but 170 kPa is excessive. Holden do not provide a specification so a known good vehicle was check and found to have 70 kPa back pressure.

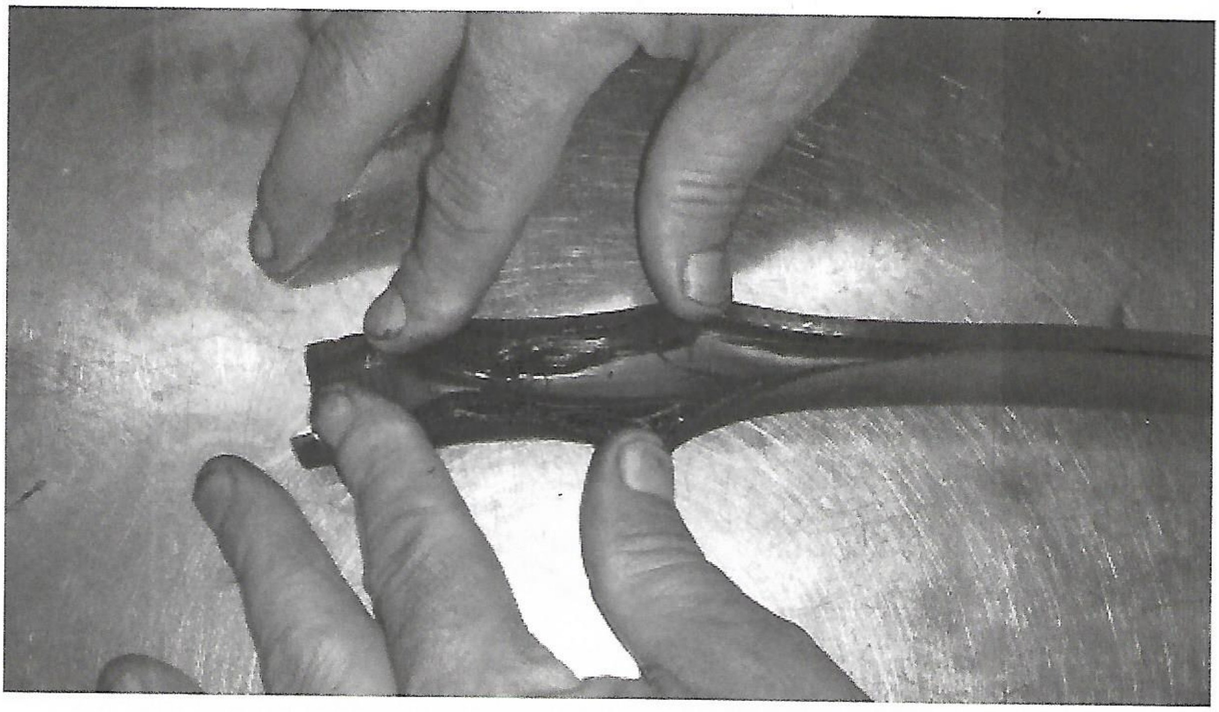
To pinpoint the restriction the return pressure was checked again at the point where it disappears above fuel tank (the return line is identified as #1).



At this point it was found to have the specified 70 kPa.

FUEL RETURN PRESSURE CASE STUDY continued...

The fuel return hose on this vehicle had been replaced as part of the long range tank modification. So the hose was removed and dissected to identify the cause.



The cause was found to be delaminated fuel hose caused by the use of fuel hose that was not diesel resistant in the long range tank modification! Because the SCV regulates the fuel input by bypassing it into the return system the restriction in the return line had taken over as the High Pressure Fuel Pump regulator.

All of the hoses in the modification were replaced with quality hoses suitable for diesel vehicles and the fault did not return.

Note: *While this fault is very specific, a restriction caused by impact damage to the return line would yield a similar result!*

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